Cleaner Production Assessment in Dairy Processing

Prepared by

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for

UNEP

United Nations Environment Programme
Division of Technology, Industry and Economics

and

Danish Environmental Protection Agency
Danish Ministry of Environment and Energy

CONTENTS

PREFACE

The purpose of the Industrial Sector Guides for Cleaner Production Assessment is to raise awareness of the environmental impacts associated with industrial and manufacturing processes, and to highlight the approaches that industry and government can take to avoid or minimise these impacts by adopting a Cleaner Production approach.

This guide is designed for two principal audiences:

- People responsible for environmental issues at dairy processing plants (environmental managers or technicians) who seek information on how to improve production processes and products. In many countries, managers are ultimately responsible for any environmental harm caused by their organisation's activities, irrespective of whether it is caused intentionally or unintentionally.
- Environmental consultants, Cleaner Production practitioners, employees of industry bodies, government officers or private consultants that provide advice to the dairy processing industry on environmental issues.

The guide describes Cleaner Production opportunities for improving resource efficiency and preventing the release of contaminants to the air, water and land. The Cleaner Production opportunities described in this guide will help improve production as well as environmental performance.

Chapter 1 provides a brief introduction to the concept of Cleaner Production and the benefits that it can provide.

Chapter 2 provides an overview of the dairy processing industry including process descriptions, environmental impacts and key environmental indicators for the industry. The processes discussed in most detail are milk, butter, cheese and dried milk production, as well as cleaning and ancillary operations.

Chapter 3 describes Cleaner Production opportunities for each of the unit operations within the process and examples where these have been successfully applied. Quantitative data are provided for the inputs and outputs associated with each unit operation as an indication of the typical levels of resource consumption and waste generation.

Chapter 4 provides a case study demonstrating the application of Cleaner Production at a dairy processing plant.

Chapter 5 describes the Cleaner Production assessment methodology in detail. This can be used as a reference guide for carrying out a Cleaner Production assessment within an organisation.

Annex 1 contains a reference and bibliography list.

Annex 2 contains a glossary and list of abbreviations.

Annex 3 contains a list of literature and contacts for obtaining further information about the environmental aspects of the industry.

Annex 4 contains background information about the UNEP Division of Technology, Industry and Economics (UNEP DTIE).

Monetary figures quoted in this guide are based on 1995–98 figures and are presented as US dollars for consistency. As prices vary from country to country and from year to year, these figures should be used with care. They are provided as indicators of capital expenditure and savings only.

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EXECUTIVE SUMMARY

This document is one in a series of Industrial Sector Guides published by the United Nations Environment Programme UNEP Division of Technology, Industry and Economics (UNEP DTIE) and the Danish Environmental Protection Agency. The documents in the series include:

- *Cleaner Production Assessment in Dairy Processing*;
- *Cleaner Production Assessment in Meat Processing*; and
- *Cleaner Production Assessment in Fish Processing*.

This document is a guide to the application of Cleaner Production in the dairy industry, with a focus on the processing of milk and milk products at dairy processing plants. Its purpose is to raise awareness of the environmental impacts of dairy processing, and to highlight approaches that industry and government can take to avoid or minimise these impacts by adopting a Cleaner Production approach.

The life cycle of milk and milk products commences with the production of fresh cow's milk on dairy farms. Milk is then processed to produce pasteurised and homogenised market milk, butter, cheese, yogurt, custard and dairy desserts etc. It may also be preserved for a longer shelf life in the form of long-life (UHT), condensed, evaporated or powdered milk products. The various products are packaged into consumer portions and distributed to retail outlets. For fresh dairy products, refrigerated storage is required throughout the life of the products to maintain eating appeal and prevent microbiological spoilage. Following use by the consumer, packaging is either discarded or recycled.

In this guide, the upstream process of fresh milk production on dairy farms and the downstream processes of distribution and post-consumer packaging management are not covered. Instead the guide focuses on the processing of key dairy products, namely market milk, butter, cheese and evaporated and powdered milk, at dairy processing plants.

The processing of milk to produce dairy products is a significant contributor to the overall environmental load produced over the life cycle of milk production and consumption. Therefore the application of Cleaner Production in this phase of the life cycle is important.

As in many food processing industries, the key environmental issues associated with dairy processing are the high consumption of water, the generation of high-strength effluent streams, the consumption of energy and the generation of by-products. For some sites, noise and odour may also be concerns.

The guide contains background information about the industry and its environmental issues, including quantitative data on rates of resource consumption and waste generation, where available. It presents opportunities for improving the environmental performance of dairy processing plants through the application of Cleaner Production. Case studies of successful Cleaner Production opportunities are also presented.

Cleaner Production

Cleaner Production is defined as *the continuous application of an integrated, preventive, environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment*.

Cleaner Production is an approach to environmental management that aims to improve the environmental performance of products, processes and services by focusing on the causes of environmental problems rather than the symptoms. In this way, it is different to the traditional ‘pollution control’ approach to environmental management. Where pollution control is an after-the-event, ‘react and treat’ approach, Cleaner Production reflects a proactive, ‘anticipate and prevent’ philosophy.

Cleaner Production is most commonly applied to production processes by bringing about the conservation of resources, the elimination of toxic raw materials, and the reduction of wastes and emissions. However it can also be applied throughout the life cycle of a product, from the initial design phase through to the consumption and disposal phase. Techniques for implementing Cleaner Production include improved housekeeping practices, process optimisation, raw material substitution, new technology and new product design.

The other important feature of Cleaner Production is that by preventing inefficient use of resources and avoiding unnecessary generation of waste, an organisation can benefit from reduced operating costs, reduced waste treatment and disposal costs and reduced liability. Investing in Cleaner Production, to prevent pollution and reduce resource consumption is more cost effective than continuing to rely on increasingly expensive ‘end-of-pipe’ solutions. There have been many examples demonstrating the financial benefits of the Cleaner Production approach as well as the environmental benefits.

Water consumption

In the dairy processing industry, water is used principally for cleaning equipment and work areas to maintain hygienic conditions, and accounts for a large proportion of total water use. Rates of water consumption can vary considerably depending on the scale of the plant, the age and type of processing, whether batch or continuous processes are used and the ease with which equipment can be cleaned, as well as operator practices. A typical range for water consumption in reasonably efficient plants is 1.3–2.5 litres water/kg of milk intake.

In most parts of the world, the cost of water is increasing as supplies of fresh water become scarcer and as the true environmental costs of its supply are taken into consideration. Water is therefore an increasingly valuable commodity and its efficient use is becoming more important.

Strategies for reducing water consumption can involve technological solutions or equipment upgrade. However substantial benefits can also be gained from examining cleaning procedures and operator practices. Some key strategies for reducing water consumption are listed below and the use of these techniques would represent best practice for the industry. By doing so, water consumption can be reduced to as little as 0.8–1.0 litres water/kg of milk intake.

- using continuous rather than batch processes to reduce the frequency of cleaning;
- using automated cleaning-in-place (CIP) systems for cleaning to control and optimise water use;
- installing fixtures that restrict or control the flow of water for manual cleaning processes;
- using high pressure rather than high volume for cleaning surfaces;

- reusing relatively clean wastewaters (such as those from final rinses) for other cleaning steps or in non-critical applications;
- recirculating water used in non-critical applications;
- installing meters on high-use equipment to monitor consumption;
- pre-soaking floors and equipment to loosen dirt before the final clean;
- using compressed air instead of water where appropriate;
- reporting and fix leaks promptly.

Effluent discharge

Most water consumed at dairy plants ultimately becomes effluent. Dairy plant effluent is generally treated to some extent on site and then discharged to municipal sewerage systems, if available. For some municipalities, dairy effluent can represent a significant load on sewage treatment plants. Effluent may also be used for land irrigation in rural areas.

Dairy processing effluent contains predominantly milk and milk products which have been lost from the process, as well as detergents and acidic and caustic cleaning agents. Milk loss can be as high as 3–4%, with the main source of loss being residues which remain on the internal surfaces of vessels and pipes, accidental spills during tanker emptying and overflowing vessels.

The organic load discharged in the effluent stream varies depending on cleaning practices and whether batch or continuous processes are used, since batch processes require a greater frequency of cleaning. A typical figure for the COD load in dairy plant effluent is about 8 kg/m^3 milk intake.

Strategies for reducing the organic load of dairy effluents focus on minimising the amount of product that is lost to the effluent stream. Some key strategies are listed below and the use of these techniques would represent best practice.

- ensuring that vessels and pipes are drained completely and using pigs and plugs to remove product residues before cleaning;
- using level controls and automatic shut-off systems to avoid spills from vessels and tanker emptying;
- collecting spills of solid materials (cheese curd and powders) for reprocessing or use as stock feed, instead of washing them down the drain;
- fitting drains with screens and/or traps to prevent solid materials entering the effluent system;
- installing in-line optical sensors and diverters to distinguish between product and water and minimise losses of both;
- installing and maintaining level controls and automatic shut-off systems on tanks to avoid overfilling;
- using dry cleaning techniques where possible, by scraping vessels before cleaning or pre-cleaning with air guns;
- using starch plugs or pigs to recover product from pipes before internally cleaning tanks.

Energy consumption

Approximately 80% of a dairy plant’s energy needs is met by the combustion of fossil fuels (coal, oil or gas) to generate steam and hot water for evaporative and heating processes. The remaining 20% or so is met by electricity for running electric motors, refrigeration and lighting.

Energy consumption depends on the age and scale of a plant, the level of automation and the range of products being produced. Processes which involve concentration and drying, for example the production of milk powder, are very energy intensive, whereas market milk, which requires only some heat treatment and packaging, requires considerably less energy. A typical range for energy consumption in plants processing milk is 0.5–1.2 MJ/kg of milk intake.

Energy is an area where substantial savings can be made almost immediately with no capital investment, through simple housekeeping efforts. Energy savings of up to 25% are possible through switch-off programs and the fine tuning of existing processes, and an additional 20% can be saved through the use of more energy-efficient equipment and heat recovery systems. Some key strategies are listed below, and the use of these techniques would represent best practice for the industry. By doing so, energy consumption for the processing of milk can be reduced to as low as 0.3 MJ/kg of milk intake.

- implementing switch-off programs and installing sensors to turn off or power down lights and equipment when not in use;
- improving insulation on heating or cooling systems and pipework etc.;
- favouring more energy-efficient equipment;
- improving maintenance to optimise energy efficiency of equipment;
- maintaining optimal combustion efficiencies on steam and hot water boilers;
- eliminating steam leaks;
- capturing low-grade energy for use elsewhere in the operation.

Evaporation of milk to produce concentrated or dried milk products is an area of high energy use but also an area were energy savings can be made. The use of multiple effect evaporation systems, combined with thermal or mechanical recompression, can provide significant savings if not already being used.

In addition to reducing a plant's demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas, purchasing electricity produced from renewable sources, or co-generation of electricity and heat on site. For some plants it may also be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

By-product management

The most significant by-product from the dairy processing industry is whey, generated from the cheese-making process. In the past, the management of whey was a problem for the industry due to the high costs of treatment and disposal. Untreated whey has a very high concentration of organic matter, which can lead to pollution of rivers and streams and also creates bad odours. A number of opportunities exist for the recovery or utilisation of the lactose and protein content of whey. However it has only been in recent years that they have become technically and economically viable.

The utilisation of by-products is an important Cleaner Production opportunity for the industry since it reduces environmental burdens and can potentially generate additional revenue.

Implementing a Cleaner Production assessment

This guide contains information to assist the reader to undertake a Cleaner Production assessment at a dairy processing plant. A Cleaner Production assessment is a systematic procedure for identifying areas of inefficient resource consumption and poor waste management, and for developing Cleaner Production options.

The methodology described in this guide is based on that developed by UNEP and UNIDO, and consists of the following basic steps:

- planning and organising the Cleaner Production assessment;
- pre-assessment (gathering qualitative information about the organisation and its activities);
- assessment (gathering quantitative information about resource consumption and waste generation and generating Cleaner Production opportunities);
- evaluation and feasibility assessment of Cleaner Production opportunities;
- implementation of viable Cleaner Production opportunities and developing a plan for the continuation of Cleaner Production efforts.

It is hoped that by providing technical information on known Cleaner Production opportunities and a methodology for undertaking a Cleaner Production assessment, individuals and organisations within the dairy industry will be able to take advantage of the benefits that Cleaner Production has to offer.

1 CLEANER PRODUCTION

1.1 What is Cleaner Production?[1]

Over the years, industrialised nations have progressively taken different approaches to dealing with environmental degradation and pollution problems, by:

- ignoring the problem;
- diluting or dispersing the pollution so that its effects are less harmful or apparent;
- controlling pollution using 'end-of-pipe' treatment;
- preventing pollution and waste at the source through a 'Cleaner Production' approach.

The gradual progression from 'ignore' through to 'prevent' has culminated in the realisation that it is possible to achieve economic savings for industry as well as an improved environment for society. This, essentially, is the goal of Cleaner Production.

Definition of Cleaner Production

Cleaner Production is defined as the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment.

- For production processes, Cleaner Production involves the conservation of raw materials and energy, the elimination of toxic raw materials, and the reduction in the quantities and toxicity of wastes and emissions.
- For product development and design, Cleaner Production involves the reduction of negative impacts throughout the life cycle of the product: from raw material extraction to ultimate disposal.
- For service industries, Cleaner Production involves the incorporation of environmental considerations into the design and delivery of services.

Difference between Cleaner Production and pollution control

The key difference between pollution control and Cleaner Production is one of timing. Pollution control is an after-the-event, 'react and treat' approach, whereas Cleaner Production reflects a proactive, 'anticipate and prevent' philosophy. Prevention is always better than cure.

This does not mean, however, that 'end-of-pipe' technologies will never be required. By using a Cleaner Production philosophy to tackle pollution and waste problems, the dependence on 'end-of-pipe' solutions may be reduced or in some cases, eliminated altogether.

Cleaner Production can be and has already been applied to raw material extraction, manufacturing, agriculture, fisheries, transportation, tourism, hospitals, energy generation and information systems.

Changing attitudes

It is important to stress that Cleaner Production is about attitudinal as well as technological change. In many cases, the most significant Cleaner Production benefits can be gained through lateral thinking,

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[1] This chapter has been adapted from a UNEP publication, *Government Strategies and Policies for Cleaner Production*, 1994.

without adopting technological solutions. A change in attitude on the part of company directors, managers and employees is crucial to gaining the most from Cleaner Production.

Applying know-how

Applying know-how means improving efficiency, adopting better management techniques, improving housekeeping practices, and refining company policies and procedures. Typically, the application of technical know-how results in the optimisation of existing processes.

Improving technology

Technological improvements can occur in a number of ways:

- changing manufacturing processes and technology;
- changing the nature of process inputs (ingredients, energy sources, recycled water etc.);
- changing the final product or developing alternative products;
- on-site reuse of wastes and by-products.

Types of Cleaner Production options

Housekeeping	Improvements to work practices and proper maintenance can produce significant benefits. These options are typically low cost.
Process optimisation	Resource consumption can be reduced by optimising existing processes. These options are typically low to medium cost.
Raw material substitution	Environmental problems can be avoided by replacing hazardous materials with more environmentally benign materials. These options may require changes to process equipment.
New technology	Adopting new technologies can reduce resource consumption and minimise waste generation through improved operating efficiencies. These options are often highly capital intensive, but payback periods can be quite short.
New product design	Changing product design can result in benefits throughout the life cycle of the product, including reduced use of hazardous substances, reduced waste disposal, reduced energy consumption and more efficient production processes. New product design is a long-term strategy and may require new production equipment and marketing efforts, but paybacks can ultimately be very rewarding.

1.2 Why invest in Cleaner Production?

Investing in Cleaner Production, to prevent pollution and reduce resource consumption is more cost effective than continuing to rely on increasingly expensive 'end-of-pipe' solutions.

Cleaner Production versus pollution control

When Cleaner Production and pollution control options are carefully evaluated and compared, the Cleaner Production options are often more cost effective overall. The initial investment for Cleaner Production options and for installing pollution control technologies may be similar, but the ongoing costs of pollution control will generally be greater than for Cleaner Production. Furthermore, the Cleaner Production option will generate savings through reduced costs for raw materials, energy, waste treatment and regulatory compliance.

Greener products

The environmental benefits of Cleaner Production can be translated into market opportunities for 'greener' products. Companies that factor environmental considerations into the design stage of a product will be well placed to benefit from the marketing advantages of any future eco-labelling schemes.

Some reasons to invest in Cleaner Production

- improvements to product and processes;
- savings on raw materials and energy, thus reducing production costs;
- increased competitiveness through the use of new and improved technologies;
- reduced concerns over environmental legislation;
- reduced liability associated with the treatment, storage and disposal of hazardous wastes;
- improved health, safety and morale of employees;
- improved company image;
- reduced costs of end-of-pipe solutions.

1.3 Cleaner Production can be practised now

It is often claimed that Cleaner Production techniques do not yet exist or that, if they do, they are already patented and can be obtained only through expensive licences. Neither statement is true, and this belief wrongly associates Cleaner Production with 'clean technology'.

Cleaner Production also covers changing attitudes and management

Firstly, Cleaner Production depends only partly on new or alternative technologies. It can also be achieved through improved management techniques, different work practices and many other 'soft' approaches. Cleaner Production is as much about attitudes, approaches and management as it is about technology.

Cleaner Production techniques already exist

Secondly, Cleaner Production approaches are widely and readily available, and methodologies exist for its application. While it is true that Cleaner Production technologies do not yet exist for all industrial processes and products, it is estimated that 70% of all current wastes and emissions from industrial processes can be prevented at source by the use of technically sound and economically profitable procedures (Baas et al., 1992).

1.4 Cleaner Production and sustainable development

In the past, companies have often introduced processes without considering their environmental impact. They have argued that a trade-off is required between economic growth and the environment, and that some level of pollution must be accepted if reasonable rates of economic growth are to be achieved. This argument is no longer valid, and the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992, established new goals for the world community that advocate environmentally sustainable development.

Economy and environment go hand in hand

Cleaner Production can contribute to sustainable development, as endorsed by Agenda 21. Cleaner Production can reduce or eliminate the need to trade off environmental protection against economic growth, occupational safety against productivity, and consumer safety against competition in international markets. Setting goals across a range of sustainability issues leads to 'win–win' situations that benefit everyone. Cleaner Production is such a 'win–win' strategy: it protects the environment, the consumer and the worker while also improving industrial efficiency, profitability and competitiveness.

Cleaner Production can provide advantages for all countries

Cleaner Production can be especially beneficial to developing countries and those undergoing economic transition. It provides industries in these countries with an opportunity to 'leapfrog' those more established industries elsewhere that are saddled with costly pollution control.

1.5 Cleaner Production and quality and safety

Food safety and food quality are very important aspects of the food industry. While food safety has always been an important concern for the industry, it has received even greater attention over the past decade due to larger scales of production, more automated production processes and more stringent consumer expectations. A stronger emphasis is also being placed on quality due to the need for companies to be more efficient in an increasingly competitive industry.

In relation to food safety, Hazard Analysis Critical Control Point (HACCP) has become a widely use tool for managing food safety throughout the world. It is an approach based on preventing microbiological, chemical and physical hazards in food production processes by anticipating and preventing problems, rather than relying on inspection of the finished product.

Similarly, quality systems such as Total Quality Management (TQM) are based on a systematic and holistic approach to production processes and aim to improve product quality while lowering costs.

Cleaner Production should operate in partnership with quality and safety systems and should never be allowed to compromise them. As well, quality, safety and Cleaner Production systems can work synergistically to identify areas for improvement in all three areas.

1.6 Cleaner Production and environmental management systems

Environmental issues are complex, numerous and continually evolving, and an *ad hoc* approach to solving environmental problems is no longer appropriate. Companies are therefore adopting a more systematic approach to environmental management, sometimes through a formalised environmental management system (EMS).

An EMS provides a company with a decision-making structure and action programme to bring Cleaner Production into the company's strategy, management and day-to-day operations.

ISO 14001

As EMSs have evolved, a need has arisen to standardise their application. An evolving series of generic standards has been initiated by the International Organization for Standardization (ISO), to provide company management with the structure for managing environmental impacts. The UNEP/ICC/FIDIC *Environmental Management System Training Resource Kit*, mentioned above, is compatible with the ISO 14001 standard.

EMS training resources

UNEP DTIE, together with the International Chamber of Commerce (ICC) and the International Federation of Engineers (FIDIC), has published an *Environmental Management System Training Resource Kit*, which functions as a training manual to help industry adopt EMSs.

2 OVERVIEW OF DAIRY PROCESSING

Primary production and dairy processing

The dairy industry is divided into two main production areas:

- the primary production of milk on farms—the keeping of cows (and other animals such as goats, sheep etc.) for the production of milk for human consumption;
- the processing of milk—with the objective of extending its saleable life. This objective is typically achieved by (a) heat treatment to ensure that milk is safe for human consumption and has an extended keeping quality, and (b) preparing a variety of dairy products in a semi-dehydrated or dehydrated form (butter, hard cheese and milk powders), which can be stored.

Focus of this guide

The focus of this document is on the processing of milk and the production of milk-derived products—butter, cheese and milk powder—at dairy processing plants. The upstream process of primary milk production on dairy farms is not covered, since this activity is more related to the agricultural sector. Similarly, downstream processes of distribution and retail are not covered.

Industry structure and trends

Dairy processing occurs world-wide; however the structure of the industry varies from country to country. In less developed countries, milk is generally sold directly to the public, but in major milk producing countries most milk is sold on a wholesale basis. In Ireland and Australia, for example, many of the large-scale processors are owned by the farmers as co-operatives, while in the United States individual contracts are agreed between farmers and processors.

Dairy processing industries in the major dairy producing countries have undergone rationalisation, with a trend towards fewer but larger plants operated by fewer people. As a result, in the United States, Europe, Australia and New Zealand most dairy processing plants are quite large.

Plants producing market milk and products with short shelf life, such as yogurts, creams and soft cheeses, tend to be located on the fringe of urban centres close to consumer markets. Plants manufacturing items with longer shelf life, such as butter, milk powders, cheese and whey powders, tend to be located in rural areas closer to the milk supply.

The general tendency world-wide, is towards large processing plants specialising in a limited range of products. There are exceptions, however. In eastern Europe for example, due to the former supply-driven concept of the market, it is still very common for ‘city’ processing plants to be large multi-product plants producing a wide range of products.

The general trend towards large processing plants has provided companies with the opportunity to acquire bigger, more automated and more efficient equipment. This technological development has, however, tended to increase environmental loadings in some areas due to the requirement for long-distance distribution.

Basic dairy processes have changed little in the past decade. Specialised processes such as ultrafiltration (UF), and modern drying processes, have increased the opportunity for the recovery of milk solids that were formerly discharged. In addition, all processes have become much more energy efficient and the use of electronic control systems has allowed improved processing effectiveness and cost savings.

2.1 Process overview

2.1.1 Milk production

The processes taking place at a typical milk plant include:

- receipt and filtration/clarification of the raw milk;
- separation of all or part of the milk fat (for standardisation of market milk, production of cream and butter and other fat-based products, and production of milk powders);
- pasteurisation;
- homogenisation (if required);
- deodorisation (if required);
- further product-specific processing;
- packaging and storage, including cold storage for perishable products;
- distribution of final products.

Figure 2–1 is a flow diagram outlining the basic steps in the production of whole milk, semi-skimmed milk and skimmed milk, cream, butter and buttermilk. In such plants, yogurts and other cultured products may also be produced from whole milk and skimmed milk.

2.1.2 Butter production

The butter-making process, whether by batch or continuous methods, consists of the following steps:

- preparation of the cream;
- destabilisation and breakdown of the fat and water emulsion;
- aggregation and concentration of the fat particles;
- formation of a stable emulsion;
- packaging and storage;
- distribution.

Figure 2–2 is a flow diagram outlining the basic processing system for a butter-making plant. The initial steps, (filtration/clarification, separation and pasteurisation of the milk) are the same as described in the previous section. Milk destined for butter making must not be homogenised, because the cream must remain in a separate phase.

After separation, cream to be used for butter making is heat treated and cooled under conditions that facilitate good whipping and churning. It may then be ripened with a culture that increases the content of diacetyl, the compound responsible for the flavour of butter. Alternatively, culture inoculation may take place during churning. Butter which is flavour enhanced using this process is termed lactic, ripened or cultured butter. This process is very common in continental European countries. Although the product is claimed to have a superior flavour, the storage life is limited. Butter made without the addition of a culture is called sweet cream butter. Most butter made in the English-speaking world is of this nature.

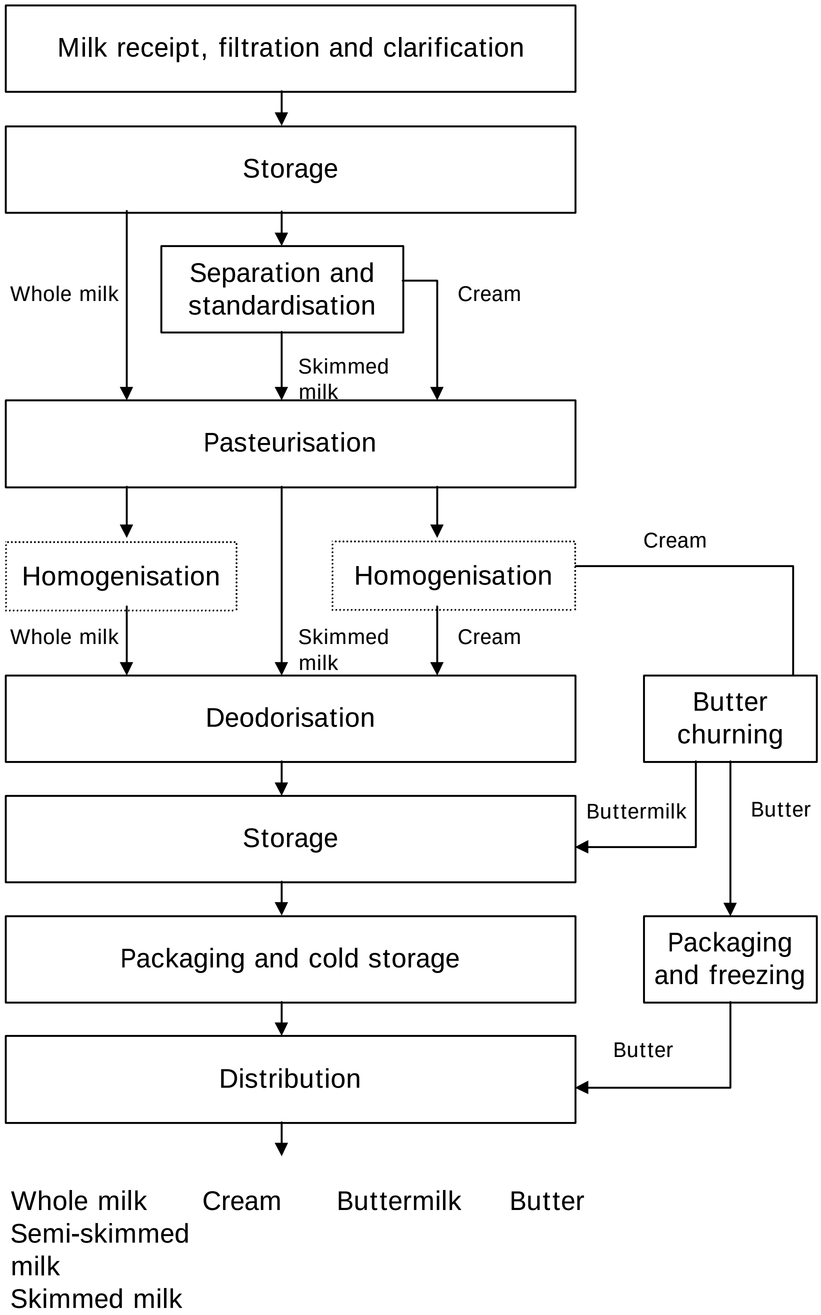

Figure 2–1 Flow diagram for processes occurring at a typical milk plant

Both cultured and sweet cream butter can be produced with or without the addition of salt. The presence of salt affects both the flavour and the keeping quality.

Butter is usually packaged in bulk quantities (25 kg) for long-term storage and then re-packed into marketable portions (usually 250 g or 500 g, and single-serve packs of 10–15 g). Butter may also be packed in internally lacquered cans, for special markets such as the tropics and the Middle East.

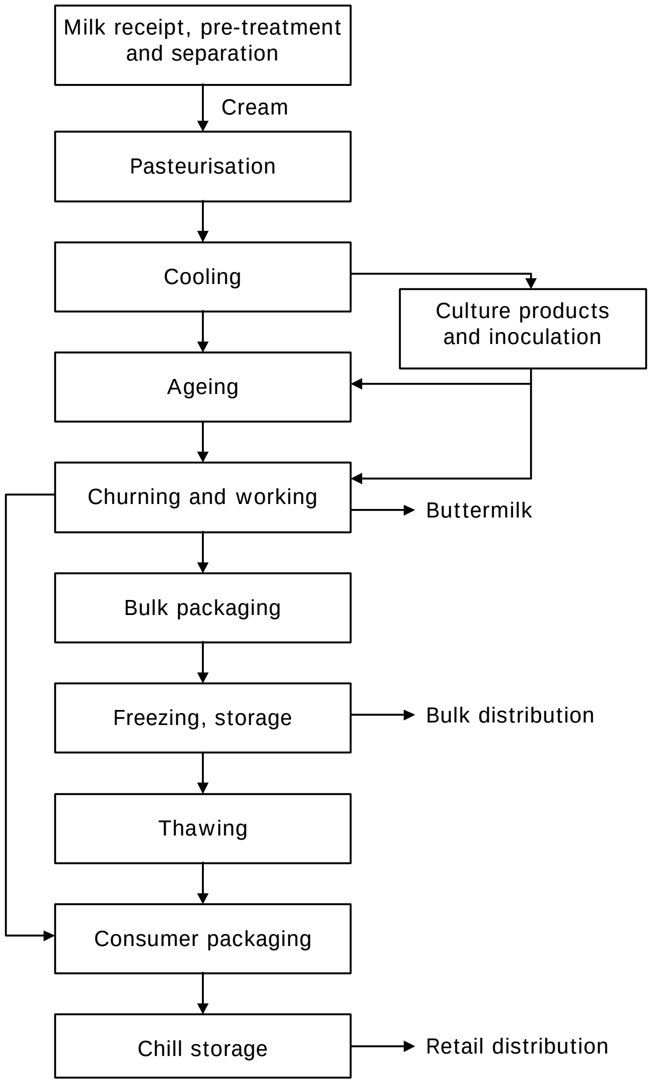

Figure 2–2 Flow diagram for a typical butter-making plant

2.1.3 Cheese production

Virtually all cheese is made by coagulating milk protein (casein) in a manner that traps milk solids and milk fat into a curd matrix. This curd matrix is then consolidated to express the liquid fraction, cheese whey. Cheese whey contains those milk solids which are not held in the curd mass, in particular most of the milk sugar (lactose) and a number of soluble proteins.

Figure 2–3 outlines the basic processes in a cheese-making plant. All cheese-making processes involve some or all of these steps.

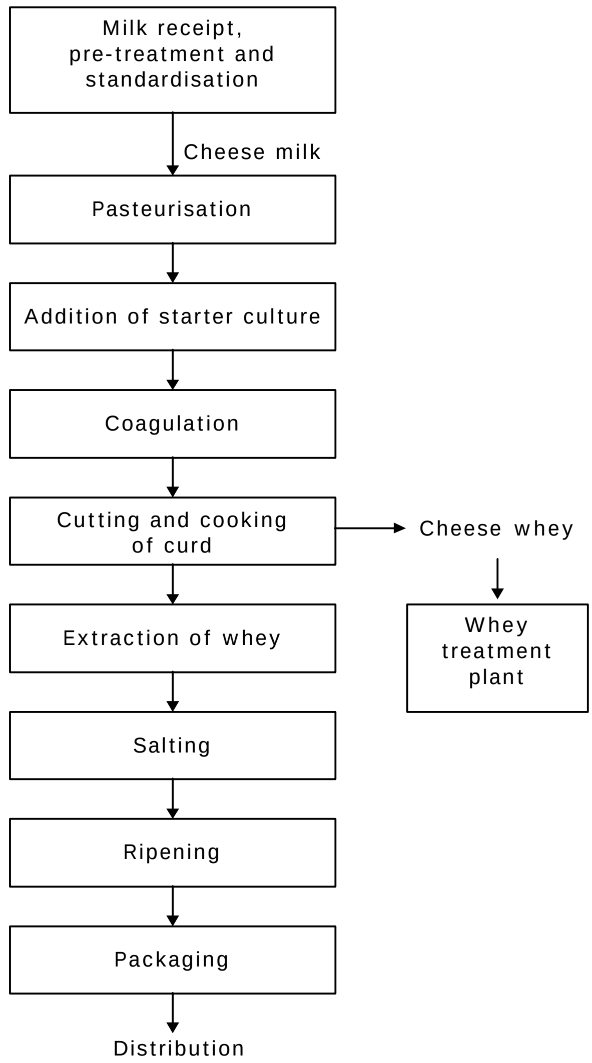

Figure 2–3 Flow diagram for a typical cheese plant

2.1.4 Milk powder production

Milk used for making milk powder, whether it be whole or skim milk, is not pasteurised before use. The milk is preheated in tubular heat exchangers before being dried. The preheating temperature depends on the season (which affects the stability of the protein in the milk) and on the characteristics desired for the final powder product.

The preheated milk is fed to an evaporator to increase the concentration of total solids. The solids concentration that can be reached depends on the efficiency of the equipment and the amount of heat that can be applied without unduly degrading the milk protein.

The milk concentrate is then pumped to the atomiser of a drying chamber. In the drying chamber the milk is dispersed as a fine fog-like mist into a rapidly moving hot air stream, which causes the individual mist droplets to instantly evaporate. Milk powder falls to the bottom of the chamber, from where it is removed. Finer milk powder particles are carried out of the chamber along with the hot air stream and collected in cyclone separators.

Milk powders are normally packed and distributed in bulk containers or in 25 kg paper packaging systems. Products sold to the consumer market are normally packaged in cans under nitrogen. This packaging system improves the keeping quality, especially for products with high fat content.

Figure 2–4 outlines the basic processes for the production of milk powder.

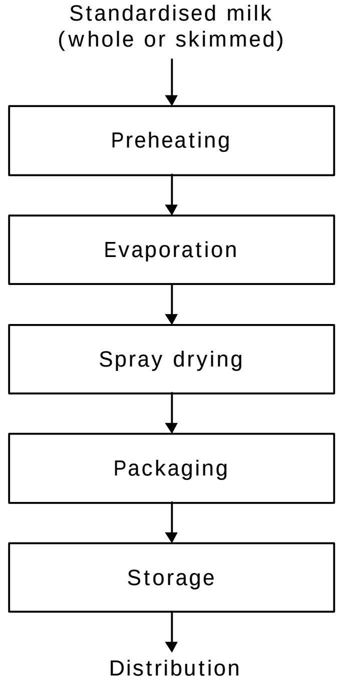

Figure 2–4 Flow diagram for a typical milk drying plant

2.2 Environmental impacts

This section briefly describes some of the environmental impacts associated with the primary production of milk and the subsequent processing of dairy products. While it is recognised that the primary production of milk has some significant environmental impacts, this document is predominantly concerned with the processing of dairy products.

2.2.1 Impacts of primary production

The main environmental issues associated with dairy farming are:

- the generation of solid manure and manure slurries, which may pollute surface water and groundwater;
- the use of chemical fertilisers and pesticides in the production of pastures and fodder crops, which may pollute surface water and groundwater;
- the contamination of milk with pesticides, antibiotics and other chemical residues.

Manure wastes

In most cases, solid manure is applied to pastures and cultivated land. The extent of application, however, may be restricted in some regions. Dairy effluent and slurries are generally held in some form of lagoon to allow sedimentation and biological degradation before they are irrigated onto land. Sludge generated from biological treatment of the dairy effluent can also be applied to pastures, as long as it is within the allowable concentrations for specified pollutants, as prescribed by regulations. Sludge can also be used in the production of methane-rich biogas, which can then be used to supplement energy supplies.

Manure waste represents a valuable source of nutrients. However improper storage and land application of manure and slurries can result in serious pollution of surface waters and groundwater, potentially contaminating drinking water supplies.

Chemical fertilisers

The extensive use of chemical fertilisers containing high levels of nitrogen has resulted in pollution of the groundwater and surface waters in many countries.

Nitrite in drinking water is known to be carcinogenic, and nitrite levels in drinking water that exceed 25–50 mg/L have been linked to cyanosis in newborn infants (‘blue babies’).

Compounds containing nitrogen and phosphorus, if discharged to surface water, can lead to excessive algal growth (eutrophication). This results in depleted dissolved oxygen levels in the water, thereby causing the death of fish and other aquatic species. In sensitive areas, therefore, the rate and manner of application of chemical fertilisers are critical.

Pesticides

The use of pesticides has been recognised as an environmental concern for many agricultural activities. Toxic pesticides, some of which biodegrade very slowly, can accumulate in body tissues and are harmful to ecosystems and to human health. Pesticides can end up in agricultural products, groundwater and surface waters, and in extreme cases can enter the human food chain through milk.

Milk contamination

For the past few decades, the contamination of milk with antibiotics has been an issue of concern. This is due to the overuse of antibiotics for treatment of cattle diseases, particularly mastitis. It has been brought under control in most countries with developed dairy industries, through strict limitations on the use of antibiotics, regular testing of milk for antibiotic residues, rigorous enforcement of regulations, and education.

In some countries, considerable attention has also been paid to the screening of milk supplies for traces of radioactivity, and most countries now apply acceptance limits for raw and imported milk products. Even the slightest levels of contamination in milk can be serious, because pollutants are concentrated in the processing process.

2.2.2 Impacts of dairy processing

As for many other food processing operations, the main environmental impacts associated with all dairy processing activities are the high consumption of water, the discharge of effluent with high organic loads and the consumption of energy. Noise, odour and solid wastes may also be concerns for some plants.

Water consumption

Dairy processing characteristically requires very large quantities of fresh water. Water is used primarily for cleaning process equipment and work areas to maintain hygiene standards.

Effluent discharge

The dominant environmental problem caused by dairy processing is the discharge of large quantities of liquid effluent. Dairy processing effluents generally exhibit the following properties:

- high organic load due to the presence of milk components;
- fluctuations in pH due to the presence of caustic and acidic cleaning agents and other chemicals;
- high levels of nitrogen and phosphorus;
- fluctuations in temperature.

If whey from the cheese-making process is not used as a by-product and discharged along with other wastewaters, the organic load of the resulting effluent is further increased, exacerbating the environmental problems that can result.

In order to understand the environmental impact of dairy processing effluent, it is useful to briefly consider the nature of milk. Milk is a complex biological fluid that consists of water, milk fat, a number of proteins (both in suspension and in solution), milk sugar (lactose) and mineral salts.

Dairy products contain all or some of the milk constituents and, depending on the nature and type of product and the method of manufacturing, may also contain sugar, salts (e.g. sodium chloride), flavours, emulsifiers and stabilisers.

For plants located near urban areas, effluent is often discharged to municipal sewage treatment systems. For some municipalities, the effluent from local dairy processing plants can represent a significant load on sewage treatment plants. In extreme cases, the organic load of waste milk solids entering a sewage system may well exceed that of the township’s domestic waste, overloading the system.

In rural areas, dairy processing effluent may also be irrigated to land. If not managed correctly, dissolved salts contained in the effluent can adversely affect soil structure and cause salinity. Contaminants in the effluent can also leach into underlying groundwater and affect its quality.

In some locations, effluent may be discharged directly into water bodies. However this is generally discouraged as it can have a very negative impact on water quality due to the high levels of organic matter and resultant depletion of oxygen levels.

Energy consumption

Electricity is used for the operation of machinery, refrigeration, ventilation, lighting and the production of compressed air. Like water consumption, the use of energy for cooling and refrigeration is important for ensuring good keeping quality of dairy products and storage temperatures are often specified by regulation. Thermal energy, in the form of steam, is used for heating and cleaning.

As well as depleting fossil fuel resources, the consumption of energy causes air pollution and greenhouse gas emissions, which have been linked to global warming.

Solid wastes

Dairy products such as milk, cream and yogurt are typically packed in plastic-lined paperboard cartons, plastic bottles and cups, plastic bags or reusable glass bottles. Other products, such as butter and cheese, are wrapped in foil, plastic film or small plastic containers. Milk powders are commonly packaged in multi-layer kraft paper sacs or tinned steel cans, and some other products, such as condensed milks, are commonly packed in cans.

Breakages and packaging mistakes cannot be totally avoided. Improperly packaged dairy product can often be returned for reprocessing; however the packaging material is generally discarded.

Emissions to air

Emissions to air from dairy processing plants are caused by the high levels of energy consumption necessary for production. Steam, which is used for heat treatment processes (pasteurisation, sterilisation, drying etc.) is generally produced in on-site boilers, and electricity used for cooling and equipment operation is purchased from the grid. Air pollutants, including oxides of nitrogen and sulphur and suspended particulate matter, are formed from the combustion of fossil fuels, which are used to produce both these energy sources.

In addition, discharges of milk powder from the exhausts of spray drying equipment can be deposited on surrounding surfaces. When wet these deposits become acidic and can, in extreme cases, cause corrosion.

Refrigerants

For operations that use refrigeration systems based on chlorofluorocarbons (CFCs), the fugitive loss of these gases to the atmosphere is an important environmental consideration, since CFCs are recognised to be a cause of ozone depletion in the atmosphere. For such operations, the replacement of CFC-based systems with non- or reduced-CFC systems is thus an important issue.

Noise

Some processes, such as the production of dried casein, require the use of hammer mills to grind the product. The constant noise generated by this equipment has been known to be a nuisance in surrounding residential areas. The use of steam injection for heat treatment of milk and for the creation of reduced pressure in evaporation processes also causes high noise levels.

A substantial traffic load in the immediate vicinity of a dairy plant is generally unavoidable due to the regular delivery of milk (which may be on a 24-hour basis), deliveries of packaging and the regular shipment of products.

Noise problems should be taken into consideration when determining plant location.

Hazardous wastes

Hazardous wastes consist of oily sludge from gearboxes of moving machines, laboratory waste, cooling agents, oily paper filters, batteries, paint cans etc. At present, in western Europe some of these materials are collected by waste companies. While some waste is incinerated, much is simply dumped.

2.3 Environmental indicators

Environmental indicators are important for assessing Cleaner Production opportunities and for assessing the environmental performance of one dairy processing operation relative to another. They provide an indication of resource consumption and waste generation per unit of production.

Figure 2–5 is a generic flowchart of the overall process including resource inputs and waste outputs. The sections that follow provide a discussion of the key inputs and outputs. Where available, quantitative data are provided.

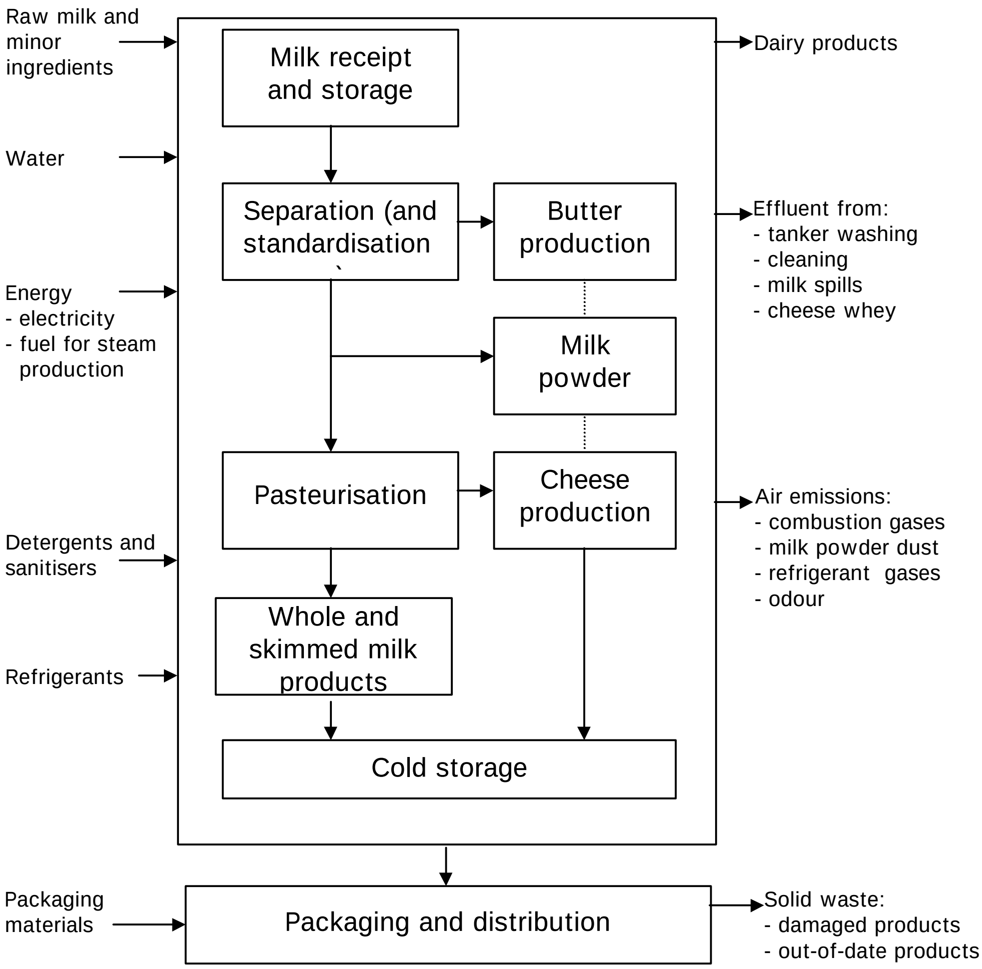

Figure 2–5 Inputs and outputs of a dairy

2.3.1 Water consumption

As with most food processing operations, water is used extensively for cleaning and sanitising plant and equipment to maintain food hygiene standards. Table 2–1 shows the areas of water consumption within a dairy processing plant, and gives an indication of the extent to which each area contributes to overall water use.

Due to the higher costs of water and effluent disposal that have now been imposed in some countries to reflect environmental costs, considerable reduction in water consumption has been achieved over the past few decades in the dairy processing industry. Table 2–2 shows the reductions in water consumption per kilogram of product that have been achieved over this period. These improvements are attributed to developments in process control and cleaning practices.

At modern dairy processing plants, a water consumption rate of 1.3–2.5 litres water/kg of milk intake is typical, however 0.8–1.0 litres water/kg of milk intake is possible (Bylund, 1995). To achieve such low consumption requires not only advanced equipment, but also very good housekeeping and awareness among both employees and management.

Table 2–1 Areas of water consumption at dairy processing plants [1]

Area of use	**Consumption** (L/kg product)	**Percentage of total**
Locker room	0.01–1.45	2%
Staff use	0.02–0.44	2%
Boiler	0.03–0.78	2%
Cold storage	0.03–0.78	2%
Receipt area	0.11–0.92	3%
Filling room	0.11–0.41	3%
Crate washer	0.18–0.75	4%
Cooling tower	0.20–1.8	5%
Cleaning	0.32–1.76	8%
Cheese room	0.06–20.89	13%
Utilities	0.56–4.39	16%
Incorporated into products	1.52–9.44	40%
TOTAL	**2.21–9.44**	**100**%

[1] Danish EPA, 1991

Table 2–2 Trend towards reduced water consumption at dairy processing plants

Water consumption (L/kg milk)		
	1973[1]	**1990s**[2]
Low consumption	2.21	
Medium consumption	3.25	1.3–2.5
High consumption	9.44	

[1] Jones, 1974

[2] Danish EPA, 1991

2.3.2 Effluent discharge

Dairy processing effluent contains predominantly milk and milk products which have been lost from the process, as well as detergents and acidic and caustic cleaning agents. The constituents present in dairy effluent are milk fat, protein, lactose and lactic acid, as well as sodium, potassium, calcium and chloride. Milk loss to the effluent stream can amount to 0.5–2.5% of the incoming milk, but can be as high as 3–4%.

A major contributing factor to a dairy plant's effluent load is the cumulative effect of minor and, on occasions, major losses of milk. These losses can occur, for example, when pipework is uncoupled during tank transfers or equipment is being rinsed. Table 2–3 provides a list of the sources of milk losses to the effluent stream.

The organic pollutant content of dairy effluent is commonly expressed as the 5-day biochemical oxygen demand (BOD_5) or as chemical oxygen demand (COD). One litre of whole milk is equivalent to approximately 110,000 mg BOD_5 or 210,000 mg COD.

Concentrations of COD in dairy processing effluents vary widely, from 180 to 23,000 mg/L. Low values are associated with milk receipt operations and high values reflect the presence of whey from the production of cheese. A typical COD concentration for effluent from a dairy plant is about 4000 mg/L. This implies that 4% of the milk solids received into the plant is lost to the effluent stream, given that the COD of whole milk is 210,000 mg/L and that effluent COD loads have been estimated to be approximately 8.4 kg/m^3 milk intake (Marshall and Harper, 1984).

A Danish survey (see text box below) found that effluent loads from dairy processing plants depend, to some extent, on the type of product being produced. The scale of the operation and whether a plant uses batch or continuous processes also have a major influence, particularly for cleaning. This is because small batch processes requires more frequent cleaning. The tendency within the industry towards larger plants is thus favourable in terms of pollutant loading per unit of production.

Water consumption survey for Danish dairy processing plants

A survey of 72 Danish dairy companies operating a total of 134 processing plants was conducted in 1989 (Danish EPA, 1991). The product mix of the companies surveyed was as follows: 44 dairies produced butter, 90 produced cheese, 29 were market milk plants and 11 produced concentrates including milk powder. The plants surveyed were all technologically advanced and most claimed that they had reduced the pollutant load of their effluents by 30–50% compared with previous years. The survey found that on average each tonne of milk processed resulted in the production of 1.3 m^3 of effluent with the following characteristics:

COD	2000 mg/L
BOD_5	1500 mg/L
Fat	150 mg/L
Total nitrogen	100 mg/L
Total phosphorus	30 mg/L

Table 2–3 Sources of milk losses to the effluent stream[1]

Process area	Source of milk loss
Milk receipt and storage	• Poor drainage of tankers • Spills and leaks from hoses and pipes • Spills from storage tanks • Foaming • Cleaning operations
Pasteurisation and ultra heat treatment	• Leaks • Recovery of downgraded product • Cleaning operations • Foaming • Deposits on surfaces of equipment
Homogenisation	• Leaks • Cleaning operations
Separation and clarification	• Foaming • Cleaning operations • Pipe leaks
Market milk production	• Leaks and foaming • Product washing • Cleaning operations • Overfilling • Poor drainage • Sludge removal from separators/clarifiers • Damaged milk packages • Cleaning of filling machinery
Cheese making	• Overfilling vats • Incomplete separation of whey from curds • Use of salt in cheese making • Spills and leaks • Cleaning operations
Butter making	• Vacreation and use of salt • Cleaning operations
Milk powder production	• Spills during powder handling • Start-up and shut-down processes • Plant malfunction • Stack losses • Cleaning of evaporators and driers • Bagging losses

[1] EPA Victoria 1997.

Due to the traditional payment system for raw milk (which is based on the mass or volume delivered plus a separate price or premium for the weight of milk fat), the dairy processing industry has always tried to minimise loss of milk fat. In many countries the payment system now recognises the value of the non-fat milk components. Systems that control the loss of both fat and protein are now common in the industrialised world, but less so in the developing world.

The disposal of whey produced during cheese production has always been a major problem in the dairy industry. Whey is the liquid remaining after the recovery of the curds formed by the action of enzymes on milk. It comprises 80–90% of the total volume of milk used in the cheese making process and contains more than half the solids from the original whole milk, including 20% of the protein and most of the lactose. It has a very high organic content, with a COD of approximately 60,000 mg/L (Morr, 1992). Only in the past two decades have technological advances made it economically possible to recover soluble proteins from cheese whey and, to some extent, to recover value from the lactose.

Most dairies are aware that fat and protein losses increase the organic load of the effluent stream and, even in the developing world, the use of grease traps has been common for some decades. Many companies, however, do not take any action to reduce the organic pollution from other milk components. It is becoming more common for dairy companies to be forced by legal or economic pressures to reduce the amount and concentration of pollutants in their effluent streams.

Therefore, at most sites, wastewater treatment or at least pretreatment is necessary to reduce the organic loading to a level that causes minimal environmental damage and does not constitute a health risk. The minimum pretreatment is usually neutralisation of pH, solids sedimentation and fat removal.

2.3.3 Energy consumption

Energy is used at dairy processing plants for running electric motors on process equipment, for heating, evaporating and drying, for cooling and refrigeration, and for the generation of compressed air.

Approximately 80% of a plant’s energy needs is met by the combustion of fossil fuel (gas, oil etc.) to generate steam and hot water for evaporative and heating processes. The remaining 20% or so is met by electricity for running electric motors, refrigeration and lighting.

The energy consumed depends on the range of products being produced. Processes which involve the concentration and drying of milk, whey or buttermilk for example, are very energy intensive. The production of market milk at the other extreme involves only some heat treatment and packaging, and therefore requires considerably less energy. Table 2–4 provides some indicative figures of specific energy consumption of different dairy products.

Table 2–4 Specific energy consumption for various dairy products [1]

Product	**Electricity consumption** (GJ/tonne product)	**Fuel consumption** (GJ/tonne product)
Market milk	0.20	0.46
Cheese	0.76	4.34
Milk powder	1.43	20.60
Butter	0.71	3.53

[1] Joyce and Burgi, 1993. (based on a survey of Australian dairy processors in 1981–82)

Energy consumption will also depend on the age and scale of a plant as well as the level of automation. To demonstrate this, Table 2–5 provides examples of energy consumption rates for a selection of Australian plants processing market milk.

Table 2–5 Energy consumption for a selection of milk plants [1]

Type of plant	**Total energy consumption** (GJ/tonne milk processed)
Modern plant with high-efficiency regenerative pasteuriser and modern boiler	0.34
Modern plant using hot water for processing	0.50
Old, steam-based plant	2.00
Range for most plants	0.5–1.2

[1] Joyce and Burgi, 1993. (based on a survey of Australian dairy processors in 1981–82)

Plants producing powdered milk exhibit a wide range of energy efficiencies, depending on the type of evaporation and drying processes that are used. Energy consumption depends on the number of evaporation effects (the number of evaporation units that are used in series) and the efficiency of the powder dryer. Table 2–6 provides examples of how different evaporation and drying systems can affect the energy efficiency of the process.

Substantial increases in electricity use have resulted from the trend towards automated plant with associated pumping costs and larger evaporators as well as an increase in refrigeration requirements.

High consumption of electricity can also be due to the use of old motors, excessive lighting or possibly a lack of power factor correction.

Table 2–6 Energy consumption for evaporation and drying systems [1]

Type of evaporation and drying system	**Total energy consumption** (GJ/tonne product)
5-effect evaporator and 2-stage drier	13–15
3-effect evaporator and 1-stage drier	22–28
2-effect evaporator and 1-stage drier	40–50

[1] Joyce and Burgi, 1993. (based on a survey of Australian dairy processors in 1981–82)

3 CLEANER PRODUCTION OPPORTUNITIES

Dairy processing typically consumes large quantities of water and energy and discharges significant loads of organic matter in the effluent stream. For this reason, Cleaner Production opportunities described in this guide focus on reducing the consumption of resources (water and energy), increasing production yields and reducing the volume and organic load of effluent discharges.

At the larger production scales, dairy processing has become an extremely automated process and resource efficiency relies, to a large extent, on the efficiency of plant and equipment, the control systems that are used to operate them and the technologies used to recover resources. As a result many Cleaner Production opportunities lie in the selection, design and efficient operation of process equipment. Operator practices also have an impact on plant performance, for example in the areas of milk delivery, plant maintenance and cleaning operations. Therefore there are also opportunities in the areas of housekeeping, work procedures, maintenance regimes and resource handling.

Section 3.1 provides examples of general Cleaner Production opportunities that apply across the entire process, whereas Sections 3.2 to 3.7 present opportunities that relate specifically to individual unit operations within the process. For each unit operation, a detailed process description is provided along with Cleaner Production opportunities specific to that activity. Where available, quantitative data applicable to each unit operation is also provided.

3.1 General

Many food processors that undertake Cleaner Production projects find that significant environmental improvement and cost savings can be derived from simple modification to housekeeping procedures and maintenance programs. Table 3–1 is a checklist of some of these ways. They are generic ideas that apply to the dairy manufacturing process as a whole.

Table 3–1 Checklist of general housekeeping ideas[1]

- Keep work areas tidy and uncluttered to avoid accidents.
- Maintain good inventory control to avoid waste of raw ingredients.
- Ensure that employees are aware of the environmental aspects of the company's operations and their personal responsibilities.
- Train staff in good cleaning practices.
- Schedule regular maintenance activities to avoid breakdowns.
- Optimise and standardise equipment settings for each shift.
- Identify and mark all valves and equipment settings to reduce the risk that they will be set incorrectly by inexperienced staff.
- Improve start-up and shut-down procedures.
- Segregate waste for reuse and recycling.
- Install drip pans or trays to collect drips and spills.

[1] UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.1 Water

Water is used extensively in dairy processing, so water saving measures are very common Cleaner Production opportunities in this industry. The first step is to analyse water use patterns carefully, by installing water meters and regularly recording water consumption. Water consumption data should be collected during production hours, especially during periods of cleaning. Some data should also be collected outside normal working hours to identify leaks and other areas of unnecessary wastage.

The next step is to undertake a survey of all process area and ancillary operations to identify wasteful practices. Examples might be hoses left running when not in use, CIP cleaning processes using more water than necessary, etc. Installing automatic shut-off equipment and restrictors could prevent such wasteful practices. Automatic control of water use is preferable to relying on operators to manually turn water off.

Once wasteful practices have been addressed, water use for essential process functions can be investigated. It can be difficult to establish the minimum consumption rate necessary to maintain process operations and food hygiene standards. The optimum rate can be determined only by investigating each process in detail and undertaking trials. Such investigations should be carried out collaboratively by production managers, food quality and safety representatives and operations staff. When an optimum usage rate been agreed upon, measures should be taken to set the supply at the specified rate and remove manual control.

Once water use for essential operations has been optimised, water reuse can be considered. Wastewaters that are only slightly contaminated could be used in other areas. For example, final rinse waters could be used as the initial rinses for subsequent cleaning activities, or evaporator condensate could be reused as cooling water or as boiler feed water. Wastewater reuse should not compromise product quality and hygiene, and reuse systems should be carefully installed so that reused wastewater lines cannot be mistaken for fresh water lines, and each case should be approved by the food safety officer.

Table 3–2 Checklist of water saving ideas [1]

- Use continuous rather than batch processes to reduce the frequency of cleaning;
- Use automated cleaning-in-place (CIP) systems for cleaning to control and optimise water use;
- Install fixtures that restrict or control the flow of water for manual cleaning processes;
- Use high pressure rather than high volume for cleaning surfaces;
- Reuse relatively clean wastewaters (such as those from final rinses) for other cleaning steps or in non-critical applications;
- Recirculate water used in non-critical applications;
- Install meters on high-use equipment to monitor consumption;
- Pre-soak floors and equipment to loosen dirt before the final clean;
- Use compressed air instead of water where appropriate;
- Report and fix leaks promptly.

[1] UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.2 Effluent

Cleaner Production efforts in relation to effluent generation should focus on reducing the pollutant load of the effluent. The volume of effluent generated is also an important issue. However this aspect is linked closely to water consumption, therefore efforts to reduce water consumption will also result in reduced effluent generation. Opportunities for reducing water consumption are discussed in Section 3.1.1.

Opportunities for reducing the pollutant load of dairy plant effluent focus on avoiding the loss of raw materials and products to the effluent stream. This means avoiding spills, capturing materials before they enter drains and limiting the extent to which water comes into contact with product residues. Improvements to cleaning practices are therefore an area where the most gains can be made. Table 3-4 contains a checklist of common ideas for reducing effluent loads.

Table 3–3 Checklist of ideas for reducing pollutant loads in effluent [1]

- Ensure that vessels and pipes are drained completely and using pigs and plugs to remove product residues before cleaning;
- Use level controls and automatic shut-off systems to avoid spills from vessels and tanker emptying;
- Collect spills of solid materials (cheese curd and powders) for reprocessing or use as stock feed;
- Fit drains with screens and/or traps to prevent solid materials entering the effluent system;
- Install in-line optical sensors and diverters to distinguish between product and water and minimise losses of both;
- Install and maintain level controls and automatic shut-off systems on tanks to avoid overfilling;
- Use dry cleaning techniques where possible, by scraping vessels before cleaning or pre-cleaning with air guns;
- Use starch plugs or pigs to recover product from pipes before internally cleaning tanks.

[1] UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.3 Energy

Energy is an area where substantial savings can be made almost immediately with no capital investment, through simple housekeeping and plant optimisation efforts.

Substantial saving are possible through improved housekeeping and the fine tuning of existing processes and additional savings are possible through the use of more energy-efficient equipment and heat recovery systems.

In addition to reducing a plant’s demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas, purchasing electricity produced from renewable sources, or co-generation of electricity and heat on site. For some plants it may also be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

Table 3–4 Checklist of energy saving ideas [1]

- Implement switch-off programs and installing sensors to turn off or power down lights and equipment when not in use;
- Improve insulation on heating or cooling systems and pipework;
- Favour more energy-efficient equipment;
- Improve maintenance to optimise energy efficiency of equipment;
- Maintain optimal combustion efficiencies on steam and hot water boilers;
- Eliminate steam leaks;
- Capture low-grade energy for use elsewhere in the operation.

[1] UNEP Cleaner Production Working Group for the Food Industry, 1999

3.2 Milk production

3.2.1 Receipt and storage of milk

Process description

Raw milk is generally received at processing plants in milk tankers. Some smaller plants may also receive milk in 25–50 L aluminium or steel cans or, in some less developed countries, in plastic barrels. Depending on the structure and traditions of the primary production sector, milk may be collected directly from the farms or from central collection facilities. Farmers producing only small amounts of milk normally deliver their milk to central collection facilities.

At the central collection facilities, operators measure the quantity of milk and the fat content. The milk is then filtered and/or clarified using centrifuges to remove dirt particles as well as udder and blood cells. The milk is then cooled using a plate cooler and pumped to insulated or chilled storage vessels, where it is stored until required for production.

Empty tankers are cleaned in a wash bay ready for the next trip. They are first rinsed internally with cold water and then cleaned with the aid of detergents or a caustic solution. To avoid build-up of milk scale, it is then necessary to rinse the inside of the tank with a nitric acid wash. Tankers may also be washed on the outside with a cold water spray.

Until required for processing, milk is stored in bulk milk vats or in insulated vessels or vessels fitted with water jackets.

Inputs and outputs

Figure 3–1 is a flow diagram showing the inputs and outputs for this process.

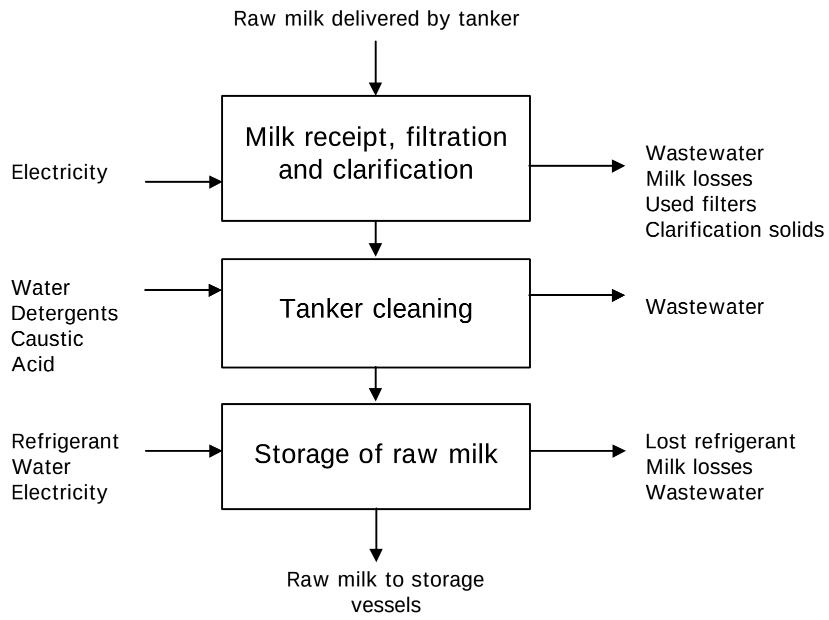

Figure 3–1 Inputs and outputs from milk receipt and storage

Environmental issues

Water is consumed for rinsing the tanker and cleaning and sanitising the transfer lines and storage vessels. The resulting effluent from rinsing and cleaning can contain milk spilt when tanker hoses are disconnected. This would contribute to the organic load of the effluent stream.

Table 3–5 provides indicative figures for the pollution loads generated from the receipt of milk at a number of plants. Table 3–6 provides indicative figures for the pollution loads generated from the washing of tankers.

Solid waste is generated from milk clarification and consists mostly of dirt, cells from the cows' udders, blood corpuscles and bacteria. If this is discharged into the effluent stream, high organic loads and associated downstream problems can result.

Table 3–5 Indicative pollution loads from the milk receival area [1]

Main product	**Wastewater** (m^3/tonne milk)	**COD** (kg/tonne milk)	**Fat** (kg/tonne milk)
Butter plant	0.07–0.10	0.1–0.3	0.01–0.02
Market milk plant	0.03–0.09	0.1–0.4	0.01–0.04
Cheese plant	0.16–0.23	0.4–0.7	0.006–0.03
Havarti cheese plant	0.60–1.00	1.4–2.1	0.2–0.3

[1] Danish EPA, 1991

Table 3–6 Indicative pollution loads from the washing of tankers [1]

Main product	**Wastewater** (m^3/tonne milk)	**COD** (kg/tonne milk)	**Fat** (kg/tonne milk)
Market milk plant	0.08–0.14	0.2–0.3	0.04–0.08
Havarti cheese plant	0.09–0.14	0.15–0.40	0.08–0.24

[1] Danish EPA, 1991

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on reducing the amount of milk that is lost to the effluent stream and reducing the amount of water used for cleaning. Ways of achieving this include:

- avoiding milk spillage when disconnecting pipes and hoses;
- ensuring that vessels and hoses are drained before disconnection;
- providing appropriate facilities to collect spills;
- identifying and marking all pipeline to avoid wrong connections that would result in unwanted mixing of products;
- installing pipes with a slight gradient to make them self-draining;
- equipping tanks with level controls to prevent overflow;
- making certain that solid discharges from the centrifugal separator are collected for proper disposal and not discharged to the sewer;
- using ‘clean-in-place’ (CIP) systems for internal cleaning of tankers and milk storage vessels, thus improving the effectiveness of cleaning and sterilisation and reducing detergent consumption;
- improving cleaning regimes and training staff;
- installing trigger nozzles on hoses for cleaning;
- reusing final rinse waters for the initial rinses in CIP operations;
- collecting wastewaters from initial rinses and returning them to the dairy farm for watering cattle.

Case study 3–1: Reduction of water consumption for cleaning

At an Estonian dairy processing plant, open-ended rubber hoses were used to clean delivery trucks. Operators used their fingers at the discharge end of the hose to produce a spray, resulting in ineffective use of water. Furthermore, the hoses were not equipped with any shut-off valve, and the water was often left running.

The operators found that they could reduce water consumption by installing high-pressure systems for cleaning the trucks, the production area and other equipment. Open-ended hoses were also equipped with trigger nozzles.

The cost of this equipment was US$6450 and the saving in water charges was US$10,400 per year; a payback period of less than 8 months. Water consumption has been reduced by 30,000 m^3/year.

3.2.2 Separation and standardisation

Process description

Dairies that produce cream and/or butter separate fat from the raw milk. Separation takes place in a centrifuge which divides the milk into cream with about 40% fat and skimmed milk with only about 0.5% fat. The skimmed milk and cream are stored and pasteurised separately.

Most dairies standardise all milk, to ensure that their products have a consistent composition. In some cases, products may need to meet certain product specifications in relation to fat content. These specifications vary from one country to the next. However in general, whole milk must contain around 3.5–4.2% fat, semi-skimmed milk around 1.3–1.5% and skimmed milk around 0.5% (Varnam and Sutherland, 1994). Standardisation is achieved by the controlled remixing of cream with skimmed milk, and is common both in cheese plants and in the production of milk powders.

Inputs and outputs

Figure 3–2 is a flow diagram showing the inputs and outputs for this process.

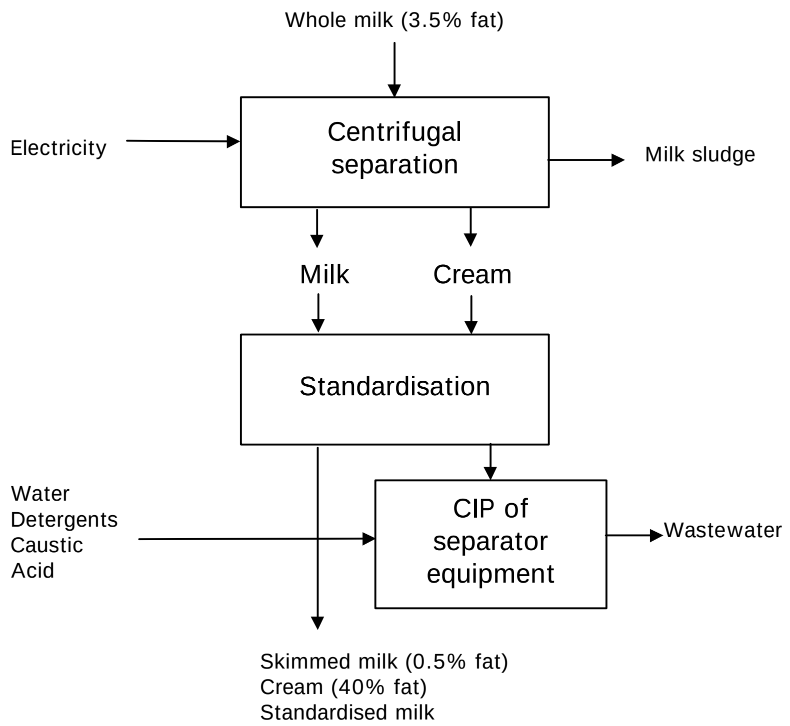

Figure 3–2 Inputs and outputs for the separation and standardisation of whole milk

Environmental issues

As in other aspects of dairy processing, water is consumed for rinsing and cleaning of process equipment, resulting in the generation of wastewaters containing milk solids and cleaning agents. Table 3–7 provides indicative figures for the pollution loads generated from the milk separation process at a number of plants.

The centrifugal separators generate a sludge material, which consists of udder and blood cells and bacteria contained in the raw milk. For standard separators the sludge is removed manually during the cleaning phase, while in the case of self-cleaning centrifuges it is discharged automatically. If the sludge is discharged to the sewer along with the effluent stream, it greatly increases the organic load of the effluent.

Table 3–7 Indicative pollution loads generated from milk separation [1]

Main product	**Wastewater** (m^3/tonne milk)	**COD** (kg/tonne milk)	**Fat** (kg/tonne milk)
Butter plant	0.20–0.30	0.3–1.9	0.05–0.40
Market milk plant	0.30–0.34	0.1–0.4	0.01–0.04
Cheese plant	0.06–0.30	0.2–0.6	0.008–0.03
Havarti cheese plant	0.60–1.00	1.4–2.1	0.2–0.3

[1] Danish EPA, 1991

Cleaner Production opportunities

Cleaner Production opportunities specific to this area are related to reducing the generation of separator sludge and optimising its collection and disposal. Ways of achieving this include:

- reducing the frequency with which centrifugal separators are cleaned, by improving milk filtration at the receiving stage or by clarification of the raw milk;
- collecting the sludge and disposing of it along with other waste solids.

Also of importance is the optimisation of cleaning processes, to make them water and energy efficient. Ways of achieving this are discussed further in section 3.6.

3.2.3 Pasteurisation and homogenisation

Process description

In large plants, milk is pasteurised in continuous flow pasteurisers, whereas some smaller dairies may use batch-type pasteurisers. In batch pasteurisation processes, milk is typically heated to 62.8–65.6°C for 30 minutes, whereas in continuous pasteurisation processes it is heated to 71.7–78.1°C for at least 15 seconds. The time–temperature relationship is usually prescribed by law, as are certain safeguards to ensure that all milk attains the minimum treatment. For both batch and continuous processes, the milk is cooled to below 10°C immediately after heating.

For some products milk is homogenised using a pressure pump, which breaks up the butterfat globules to a size that keeps them in suspension. In continuous pasteurisation processes homogenisation is usually undertaken in conjunction with pasteurisation, since its efficiency is improved if the milk is warm.

Inputs and outputs

Figure 3–3 is a flow diagram showing the inputs and outputs for this process.

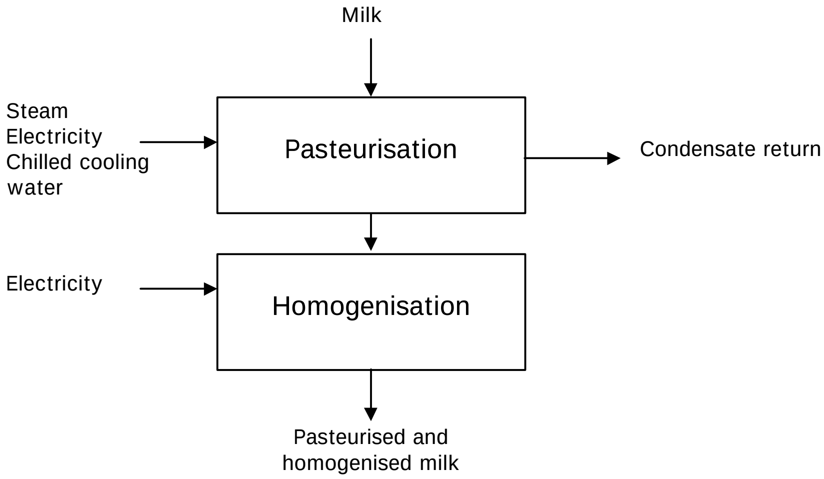

Figure 3–3 Inputs and outputs for the pasteurisation and homogenisation of whole milk

Environmental issues

The main environmental issue associated with pasteurisation and homogenisation is the high levels of energy consumed for the heating and cooling of milk.

In addition, water is consumed for rinsing and cleaning of process equipment, resulting in the generation of wastewaters containing milk solids and cleaning agents. In batch pasteurisation, small batches necessitate frequent cleaning, therefore losses of milk and the organic loads in wastewater streams are increased.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on improving energy efficiency. Ways of achieving this include:

- replacing batch pasteurisers with a continuous process incorporating plate heat exchanger (PHE) pasteurisers, where feasible. PHE pasteurisers are more energy efficient than batch pasteurisers because the heat from the pasteurised milk can be used to preheat the incoming cold milk (regenerative counter-current flow);
- installing new manufacturing equipment, which will result in less waste of milk products than the equipment currently used in many dairies;
- avoiding stops in continuous processes. The more constant the production, the less milk will be lost, since most waste comes from cleaning of batch process equipment. In the event of upgrades to process equipment, high-volume pasteurising units should be considered;
- reducing the frequency of cleaning of the pasteuriser. Particularly for small dairies, optimising the size of balance tanks before and after the pasteuriser will allow continuous operation of the pasteuriser and reduce cleaning frequency;
- planning production schedules so that product change-overs coincide with cleaning regimes;
- collecting and recovering the milky wastewater generated at start-up of pasteurisation and supplying it to farmers as animal feed.

Also of importance is optimisation of cleaning processes, to make them water and energy efficient. Ways of achieving this are discussed further in section 3.6.

To make possible the reprocessing of excess milk returned from the market, dairy plants may wish to consider developing policies which allow for the reprocessing of milk without affecting the quality of the freshly pasteurised product.

The introduction of poorer quality milk into the pasteurisation process can result in milk scale and coagulation problems due to higher acidity. This may cause higher milk losses in the pasteuriser due to the need for more frequent cleaning in order to remove milk scale. These issues should be weighed against the benefits of reprocessing returned milk.

The controlled return and reprocessing of milk from the market may require training of sales representatives. Alternatively, penalties could be applied for inappropriate ordering, or bonuses paid for extended periods of no market returns.

3.2.4 Deodorisation

Process description

Many dairies remove unwanted taints and odours from milk in deodorisation units. In these systems, the odorous substances are drawn-off by injecting steam into the system under vacuum. In situations where the taints and odours are only mild, a vacuum alone may be used.

Inputs and outputs

Figure 3–4 is a flow diagram showing the inputs and outputs for this process.

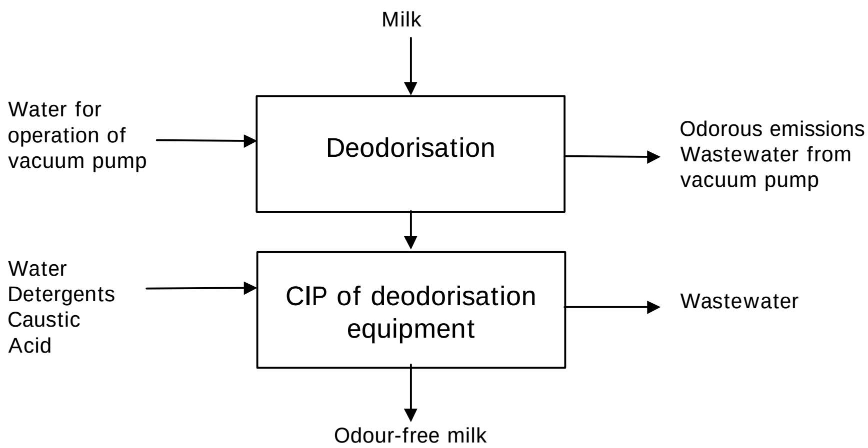

Figure 3–4 Inputs and outputs for the deodorisation of milk

Environmental issues

An environmental issue specific to the deodorisation process is the large volume of water used to operate water seals on the vacuum pump.

Cleaner Production opportunities

Water used for the vacuum pump can be recirculated to reduce or eliminate the necessity to discharge it.

3.2.5 Storage and packaging

Process description

Due to the large range of products produced at many dairies (e.g. different fat contents or heat treatment regimes), the bulk storage of these products can involve very extensive storage systems, with associated vessels, piping and valves.

Milk is packaged or bottled in a number of types of containers, including glass bottles, paper cartons, plastic bottles and plastic pouches. In most cases, filling of containers is highly automated. After filling, the packaged milk products are usually stored and transported in wire or plastic crates.

Finished products are held in refrigerated storage until dispatched to retail outlets. The storage temperature depends on the product, but for milk and fresh dairy products, the optimum temperature is usually $<4°C$. Refrigerated storage chambers are usually cooled using forced draft evaporators chilled by a primary refrigerant. A secondary refrigerant such as ice water, brine or glycol recirculated in a closed circuit cooling system is also sometimes used. Door openings are usually sealed with rubber swing doors and/or air curtains when open.

Inputs and outputs

Figure 3–5 is a flow diagram showing the inputs and outputs for this process.

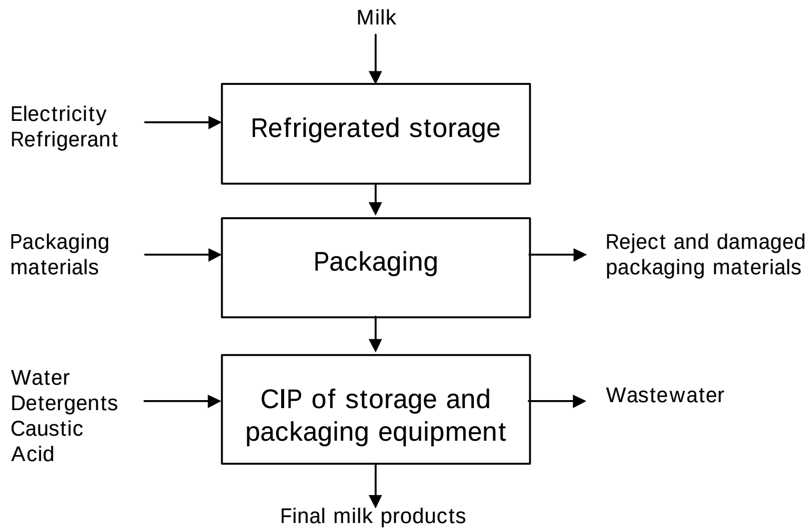

Figure 3–5 Inputs and outputs for storage and packaging of milk products

Environmental issues

The main environmental issues associated with the storage and packaging operations are the loss of milk products from spills and packaging mistakes, generation of wastewater from cleaning processes and energy consumed for refrigerated storage. However the choice of packaging materials is becoming an increasingly important issue.

Milk products can be lost to the wastewater stream during start-up and shut-down, from residues remaining in storage vessels and from the initial cold water rinses of packaging and storage equipment. Milk products may also be lost due to breakage of packaging material. Generally, incorrectly filled packages are emptied and the milk is returned to the milk receival area.

Considerable work has been undertaken to determine the most suitable form of packaging in terms of overall environmental impacts. Although glass bottles can be cleaned and recycled (thereby creating minimal solid waste), cleaning them consumes water and energy. Glass recycling systems require large capital investments and involve high running costs since the bottles must be collected, then transported and cleaned. Glass bottles can also be inconvenient for consumers because they are heavier and more fragile than cartons.

Cartons, on the other hand, create solid waste that must be transported and disposed of. Solid waste can be disposed of in a landfill, incinerated, or composted. All of these disposal alternatives have environmental impacts, including the generation of leachate from landfills and air pollution from incineration.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on improving the energy efficiency of refrigeration systems and optimising CIP processes to reduce both water use and the organic load discharged into the effluent stream. Ways of achieving this include:

- clearing milk residues from the pipes using compressed air before the first rinse;
- collecting the more highly concentrated milk wastewater at start-up and shut-down for use as animal feed;
- optimising the accuracy of filling operations. This will not only result in improved efficiency, but will also reduced potential for waste and spillage. Minor variations in filling performance can have significant cumulative effects particularly for small unit fill quantities;
- improving procedures for recovering milk from wrongly filled containers;
- emptying and collecting product from wrongly filled containers for use as animal feed;
- reducing energy consumption through improved insulation, closing of doors to cold areas, good maintenance of room coolers and regular defrosting;
- using direct ammonia-based cooling systems instead of CFC-based systems.

Case study 3–2: Minimising loss of milk in packaging

At a plant producing market milk, the filling of containers was usually undertaken in batches. The product remaining in the bottom of the supply vessel at the end of the batch was discharged to sewer. However, due to increasing effluent discharge costs, the dairy decided to return the residual milk to the production process.

This simple modification prevented 11,500 L/year of product being discharged to sewer. The value of this material was US$4850/year (US$0.42/litre) and annual effluent charges fell by US$1150. Overall the dairy saved US$6000/year with no capital expenditure.

3.3 Butter production

The primary objective of butter making is to conserve the fatty portion of the milk in a form that can be used at a later date. It is essentially a dehydration process, in which the majority of the aqueous phase is removed and the remainder is emulsified into the fat. Milk is an emulsion of milk fat in water, whereas butter is an emulsion of water in milk fat. Butter production involves the conversion from one state to the other.

The evolution of the butter-making process has progressed from the use of skins and gourds for churning, through to the use of wooden-barrelled butter churns, which have since been exchanged for stainless steel churns. Although the development of the continuous process in the 1950s led to the replacement of the batch process in most industrial plants, the batch or churn process may still be used in smaller dairies.

In batch processes, prepared cream is agitated in a specially designed vessel (butter churn) until phase inversion occurs and the fat 'breaks' from the cream in the form of butter grains. The surrounding liquid—the buttermilk—is then decanted off. The butter grains are washed in fresh chilled water, salted (if required) and worked by a shearing process to produce a homogeneous mass with a controlled moisture content.

In the more common continuous process, phase inversion of the cream, working of the butter, the addition of salt and moisture control take place in cylindrical, rotating chambers which progressively lead the butter mass to blending augers and final extrusion. The continuous process reduces the amount of waste generated by the process by eliminating the butter grain washing step and also by making use of an internal mechanical system for continuous recovery of butter 'fines'.

3.3.1 Cream treatment: ripened cream process

Process description

Pasteurisation of the cream for making cultured butter is normally carried out at temperatures of up to 110°C. The cream may be subjected to vacuum treatment during cooling in order to improve its spreadability.

In the production of ripened butter, the cream is cooled, inoculated with a culture and ripened. After a ripening period of 12–18 hours at 20°C, the cream is cooled to below 10°C.

The cream treatment process has received considerable attention over many years because it affects the quality of the final product. The quality of the fat before it is churned affects product losses from the process.

The optimum temperature for ageing the cream (allowing all fat to become solid) is generally lower than the temperature required for efficient churning. Cream that is too cold is therefore susceptible to damage, and may result in blocked pipeline and excessive loss.

The most effective churning temperature for cream can be achieved by using heat exchangers with a low pressure drop and a minimum temperature differential between the cream and the water. This avoids localised overheating.

Inputs and outputs

Figure 3–6 is a flow diagram showing the inputs and outputs for this process.

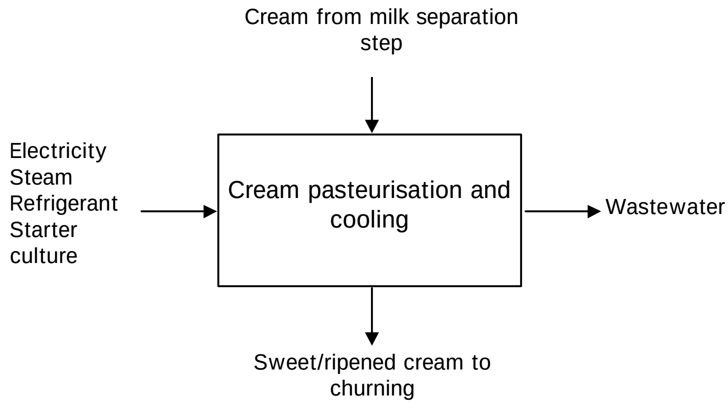

Figure 3–6 Inputs and outputs for the ripened cream process

Environmental issues

The main environmental issue associated with this process is the high organic load in wastewaters generated from rinsing and cleaning the pasteuriser. This can be further exacerbated by the requirement for frequent cleaning, which results in a greater loss of milk solids.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on reducing water use and loss of product. Ways of achieving this include:

- minimising the number of times the pasteuriser is cleaned. Particularly in small butter dairies, optimising the size of balance tanks before and after the pasteuriser will allow it to operate continuously, resulting in less need for cleaning;
- installing modern pasteurising equipment. This will reduce waste of cream in many dairies, because improvements in plate design now give a more gentle and constant heat treatment. This decreases the build-up of overheated solids on heating surfaces. In the event of upgrades to process equipment, high-volume pasteurising units should be considered;
- collecting the more highly concentrated milk wastewater generated when starting up the pasteuriser, for use as animal feed.

3.3.2 Butter churning

Process description

The cream enters the butter maker and the fat globules are disrupted under controlled conditions to destabilise the emulsion and agglomerate the milk fat. This is achieved in the first churning cylinder, which is fitted with a beater driven by a variable-speed motor. The beater speed is adjusted to give the desired butter grain size with minimum fat loss in the buttermilk.

To maintain steady butter-making conditions, it is essential that the cream feed rate be constant. This can be achieved by using a balance tank between the ageing silo and the pump.

The mixture of butter grains and buttermilk falls from the first cylinder into the back section of a second cylinder, where the grains are consolidated. This second cylinder is a larger, perforated, slowly rotating drum which causes the grains to travel along an inclined rotating screen with a tumbling action, thus assisting their aggregation at the same time as they are drained of buttermilk. The buttermilk is pumped away from below the cylinder.

From the second cylinder, the moist grains of butter fall into the worker compartment which uses contra-rotating augers to compact the grains into a heterogeneous mass, expelling more buttermilk from the grains as they are squeezed together. Compacted butter grains are fed from the auger through a series of alternating perforated plates and impeller blades. These apply shear forces that further consolidate the butter grains and break up the droplets of buttermilk now remaining in the fat matrix. This forms a dispersed aqueous phase of what is now a water-in-oil emulsion. A second worker compartment, operating under vacuum, may be incorporated to obtain a denser, finer-textured product. A second set of augers removes the butter and forces it through a final set of orifice plates and blades which complete the emulsification before the product is discharged from the butter maker.

Inputs and outputs

Figure 3–7 is a flow diagram showing the inputs and outputs for this process.

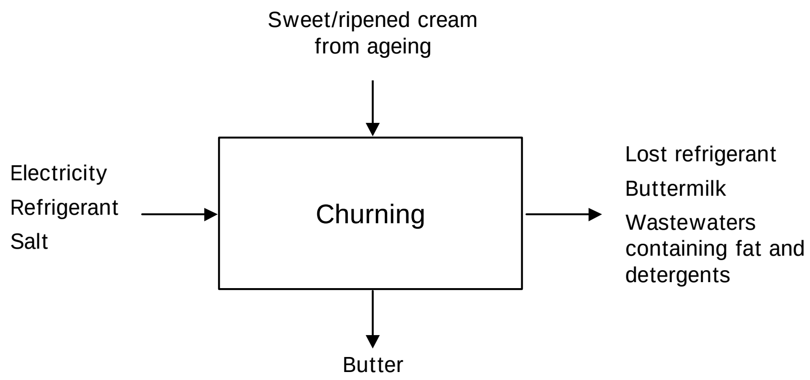

Figure 3–7 Inputs and outputs of the churning process

Environmental issues

Unless the buttermilk is used as a product or as an ingredient in other products, the quantities of buttermilk produced (about 50% of the original cream volume) represent a potential environmental loading. Pollutant discharge is greatest when a continuous butter maker is closed down, due to the loss of the fat remaining in the machine.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on reducing loss of product. Ways of achieving this include:

- ensuring that the buttermilk is collected separately and hygienically so that it can be used in other processes, such as a base for low-fat spreads;
- collecting all first rinses, and separating the residual fat for use in other processes;
- preventing the build-up of milk scale deposits;
- maintaining butter makers on a regular basis;
- avoiding spills by ensuring that the buttermilk collection facilities are large enough to hold all the liquid.

3.3.3 Butter packaging

Process description

Butter may be discharged from the butter maker directly into the feed hopper of a bulk butter packer. However, it is more commonly discharged to a butter silo fitted with a pump, thus avoiding any discontinuities in production. From the silo, butter is pumped to the packing machines through pressure compensators, which control the shear forces.

Butter can be packed initially into 25 kg cases, and subsequently repacked into consumer portions. Alternatively, consumer portions can be packed directly from the continuous butter maker. Most consumer portions are packed in a film wrap (either vegetable parchment or a parchment-lined aluminium foil) or in plastic tubs, which are becoming increasingly popular.

Repackaging of bulk butter into consumer portions requires that the frozen butter first be allowed to reach an optimum temperature of 6–8°C, under controlled humidity conditions to avoid excessive condensation. Heat for this process can be provided by carrying out the first stage of thawing in a packed butter store, or low-grade heat from recovery processes.

After temperature adjustment and before repackaging, the butter is re-blended to break down the matrix of fat crystals and to re-introduce plasticity. At this stage, there is the opportunity to adjust salt and moisture content to the maximum permitted by local regulation. For repackaging in large quantities, continuous butter blenders are available which incorporate all functions of chopping and blending and prod for in-line addition of salt, water and culture. Their construction is similar to that of a continuous buttermaker.

Inputs and outputs

Figure 3–8 is a flow diagram showing the inputs and outputs for this process.

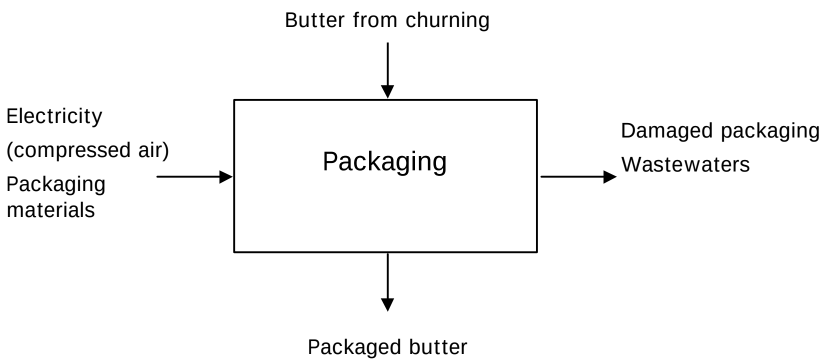

Figure 3–8 Inputs and outputs of the butter packaging process

Environmental issues

The main environmental issue associated with this process are the high organic loads in the wastewaters generated from rinsing and cleaning the equipment. The greatest potential for environmental loading occurs when machines, such as a continuous butter blender or packing machines, are closed down, because of the residual fat they contain.

In addition, product loss may occur when packaged products containing product residues are discarded.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on reducing water use and loss of product. Ways of achieving this include:

- collecting first rinses while still warm and separating the milk fat residues for use in other processes;
- reducing the disposal of packaging material by having personnel constantly optimising operation of the packaging machines.

3.3.4 Butter storage

Bulk-packed butter is a relatively stable commodity at low temperatures. Commercial freezing stores operate at temperatures down to –30°C, at which temperature the butter should remain in satisfactory condition for more than one year. If storage periods of more than one year are necessary, or if low-temperature refrigerated storage cannot be guaranteed throughout the entire storage life of the butter, the butter can dehydrate below the optimum moisture content.

Factors affecting the ability of butter to withstand long-term storage include:

- the cleanliness and hygiene of butter-making operations at all stages;
- the prevention of post-pasteurisation contamination during the addition of salt, moisture etc., and in particular the absence of micro-organisms that grow at low temperatures in the water used for these purposes;
- the degree to which salt (if added) is dispersed to the aqueous phase;
- the overall quality of the butter in terms of its homogeneity, texture and moisture distribution;
- the type of butter.

Process description

In order to standardise its consistency and appearance, butter for immediate consumption is placed in cold storage at 5°C for 24–48 hours. This ensures that fat crystallisation is complete and individual packs are firm enough to withstand subsequent transportation to the market.

For long-term storage, butter freezing facilities must operate at below –15°C, and temperatures down to –30°C are not uncommon. Sufficient space should be allowed between cases and pallets to allow air circulation, which encourages even chilling.

Refrigeration is usually, but not always, provided by direct expansion ammonia evaporators. Chambers are normally equipped with fork-lift truck access doors protected with automatic door or curtain openers.

Inputs and outputs

Figure 3–9 is a flow diagram showing the inputs and outputs for this process.

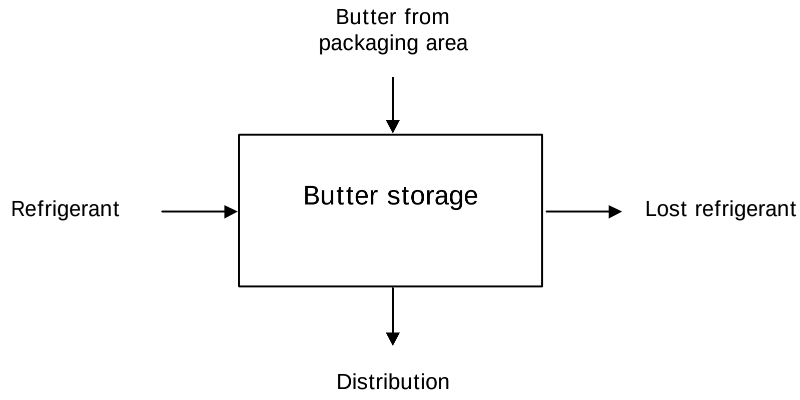

Figure 3–9 Inputs and outputs of butter storage

Environmental issues

The main environmental issue associated with the storage of butter is the energy consumed for refrigeration and the potential loss of refrigerant to the atmosphere.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on improving the energy efficiency of refrigerated storage. Ways of achieving this include:

- installing insulation;
- keeping doors closed in cold areas;
- undertaking regular defrosting of cold rooms and regular maintenance of refrigeration systems;
- avoiding refrigerants that contain CFCs. Refrigeration systems based on ammonia cooling are preferred.

3.4 Cheese production

Cheese making is an art that is more than 5000 years old. The predominantly rural character of everyday life in the past contributed to the evolution of thousands of different types of cheese and each village, or even family, may have had its own variety, some soft and short lived, some harder and more durable.

Modern cheese technology was founded in the nineteenth century when Joseph Harding perceived a need to adopt strict hygiene and control over methods of making cheddar cheese. This represented a step forward in the scientific approach to cheese making.

Cheeses can be categorised according to the following attributes:

- fat content (high-fat, semi-fat and low-fat cheeses);
- consistency (soft cheeses have a moisture content of 45–50% and semi-hard cheese below 40%);
- method of preparation and production (soft cheeses retain whey in the curd matrix and have coagulation temperatures of 20–40°C; semi-hard cheeses receive more draining and the curd is heated to 42–48°C; hard ‘cooked-curd’ cheeses are well drained and heated to 52–55°C).

Some other types of cheese include:

- fresh cheese that can be consumed just after manufacturing and salting (e.g. quark);
- acid-curd cheeses that are coagulated at a higher temperature (e.g. ricotta);
- lactic-curd cheeses which are kneaded or spun (e.g. mozzarella);
- soft cheeses that ripen for only a short time;
- cheeses that develop different tastes due to enzyme action of surface bacteria;
- blue cheeses of many flavours and types;
- semi-hard, mild-tasting, pressed cheeses with holes (e.g. gouda, havarti and tilsit);
- very hard, dry cheeses which are used for grating (e.g. parmesan).

The process description that follows is for the production of cheddar cheese. Cheddar cheese has been used as an example because it is the most widely manufactured and consumed cheese in the world and its industrial manufacturing has been largely automated.

The manufacture of cheddar cheese demonstrates most of the principles of the industrial processing of cheese and provides a good example for discussing the pertinent environmental issues of cheese making.

3.4.1 Cheddar cheese production

Process description

Whole or standardised milk is usually pasteurised at 70°C for 15 seconds and then cooled to the inoculation temperature of 30°C before being poured into a cheese vat fitted with internal agitators. If milk is received on one day and held overnight before being used for cheese production, it will be cooled to 4°C after pasteurisation, and warmed up to inoculation temperature for cheese making.

The starter culture is prepared the day before by the laboratory and may be a single-strain or mixed-strain culture, depending on the flavour required and on the cheese makers' experience. It is important that the mother cultures from which the daily starter is produced be kept under extremely hygienic conditions in order to avoid contamination—especially from bacteriophages. These are viruses that kill bacteria and can stop cheese-making operations without warning. Each is specific to a bacterial strain, and for this reason the type of starter used is 'rotated' frequently.

Generally, starter is added at the rate of 1–1.5% of the volume of cheese milk. The quantity, however, is determined on a case-by-case basis, depending on starter activity and the subsequent rate of acid development in the cheese milk.

When the acidity has reached the required level, usually after 45–60 minutes, rennet is added and dispersed evenly throughout the milk, after which curd formation begins. Rennet acts to coagulate the milk solids into curd.

When the curd is firm enough it is carefully cut into cubes the size of large peas. Cutting is done using multiple knives mounted on a frame, which is driven through the curd in two planes.

The mixture of curd pieces and whey is then gradually heated through the walls of the cheese vat to a temperature of 39°C, with slow and careful agitation. Heating assists the process of syneresis, whereby the protein structure shrinks slightly due to the action of the heat, thus expressing whey and creating a firmer curd. During the process of syneresis it is important that the curd pieces not be damaged by the agitators; this could result in a cloudy whey and high losses of fat.

When cooking is complete (determined by acidity development and curd structure) the curd pieces are allowed to settle and the whey is drained off. The curd is now one cohesive mass.

Although the process described applies to cheddar cheese, it is similar to that used for other pressed cheese processes. The primary objective is to force whey out of the curd through the action of acidity development, heat and pressure.

The curd mass is divided with a knife into blocks. These blocks are turned over and rotated regularly and stacked two or three high. They become thinner as a result of the pressing action. The blocks are kept together as much as possible to maintain warmth. This process continues until the curd texture and the acidity of the whey draining out are at optimum levels. The curd blocks are then milled into pieces about the size of large potato chips.

Dry salt is added to the milled pieces and thoroughly mixed, after which the curd pieces are filled into moulds and pressed overnight. The whey that is expelled from the press station is salt whey and is often white. The moulded blocks of cheese are removed from the moulds and allowed to dry. They are then wrapped in an impervious material—usually a plastic shrink-wrap—and transferred to a ripening room where they remain for about two months, under controlled temperature and humidity, before sale.

Due to the airtight wrapping, maturation during storage is minimal. As a result the majority of cheddar cheeses are mild and bland in flavour and since no rind is formed, all of the cheese can be consumed. So-called 'farmhouse' cheddar cheese is formed and wrapped in a cheesecloth gauze instead of plastic film and is matured for up to six months. This allows the cheese to mature properly and gas to escape slowly, resulting in a product that has fuller flavour, buttery texture and thin rind.

Inputs and outputs

Figure 3–10 is a flow diagram showing the inputs and outputs for this process.

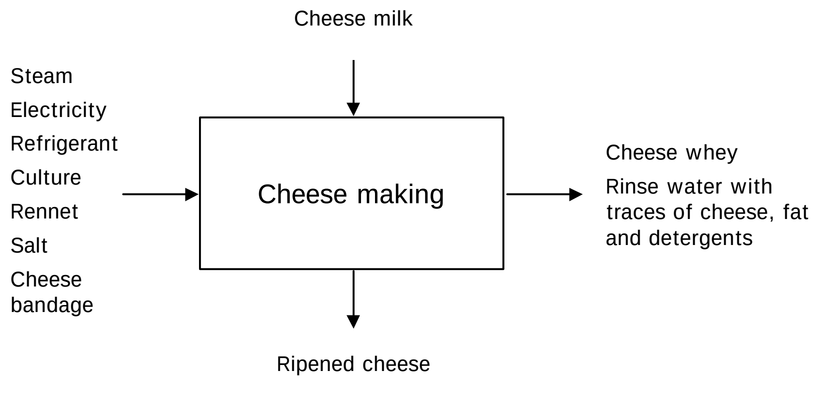

Figure 3–10 Inputs and outputs for Cheddar cheese production

Environmental issues

The major environmental issue associated with the cheese-making process is the disposal of whey. There are generally three types of whey:

- sweet whey, which is generated when enzymes, principally rennet, are used to coagulate the milk. Sweet whey typically contains 0.6–0.9% soluble protein, up to 0.3% fat and large quantities of lactose (up to 5%). The pH value of sweet whey from cheddar cheese manufacturing is generally 5.1–5.3;
- acid whey, which is generated when acid is used to coagulate the milk, for example in the production of cottage cheese. Acid whey typically contains the same proportion of soluble proteins as sweet whey, but less fat and somewhat less lactose (4.5%), since some of the lactose is converted to lactic acid. It has a low pH value, between 4.5 and 4.7;
- salt whey, which is the product expressed during the pressing of salted cheese curd, such as in the manufacturing of cheddar cheese. This whey should be collected separately from other types of whey.

Whey produced from natural cheese-making operations contains approximately 6% solids. In the past, whey was perceived merely as an insurmountable problem for the dairy industry because of the high costs of disposal using traditional effluent treatment processes. All too often dairies have taken the easy way out by simply dumping it on land, into rivers or down boreholes. Because of its lactose and protein content, untreated whey has a very high concentration of organic matter which can lead to pollution of rivers and streams and can create bad odours.

Cleaner Production opportunities

A number of opportunities exist for the recovery of the valuable high-grade protein from sweet whey. However it has only been in recent years that they have become technically and economically viable. The method used is ultrafiltration (UF), followed by spray drying of the protein. This process is costly, so is only worthwhile when large quantities of fresh whey are available. Spray-dried whey powder contains between 25% and 80% protein and is used in food products, where it performs a similar function to egg proteins. Whey powder is highly soluble, even at high acidity, and is capable of forming stable foams and gels when heated. Whey protein powder is therefore used in the manufacturing of bakery and meat products, where its gelatinous properties are particularly useful.

Other options available for whey utilisation are:

- *Evaporation followed by spray drying to produce whey powder*

  One of the problems associated with this solution is that the lactose tends to caramelise, making any heating process difficult. Unless special precautions are taken, the resulting product is very hygroscopic due to the high concentrations of lactose (70–75%). Whey powder in this form is not suitable for use as a food ingredient because it is very sticky and absorbs moisture during storage, forming hard lumps.

  Non-hygroscopic whey powder can be produced by precrystallising the lactose before drying. In this way, most of the lactose is present in the alpha-crystalline form, which is non-hygroscopic. Higher-quality whey powder can be produced by incorporating a secondary crystallisation step after spray drying.

Powder is removed from the drying chamber at 8–14% moisture. The moisture remaining in the powder permits almost complete crystallisation of the lactose and the residual moisture can then be removed in a secondary drying system (e.g. a fluid bed) before the powder is cooled and packaged.

- *Feeding it to animals*

  In most countries where this is practised, the whey is normally fed to pigs or cows. This is a low-cost solution but the price obtained for whey, after transport costs are considered, is often only a very small fraction of the cost of the original milk. The advantages are that there are no capital costs and no effluent charges.

- *Demineralisation, or reduction of the mineral content of whey*

  This increases the range of opportunities for its use as a food ingredient. Ion exchange treatment or electrodialysis is used in the demineralisation process, and demineralised whey is spray-dried in the same way as whey powder. The main use of demineralised whey powder is in the manufacture of infant milk formulations, where it is used in combination with skimmed milk powder to give a similar composition to that of human milk. Another use of demineralised whey powder is in the manufacture of chocolate. Electrodialysis, or ion exchange technology, is comparatively expensive but it does give an end product with a higher value.

- *Anaerobic digestion and fermentation*

  Whey can be anaerobically digested to produce methane gas, which can be captured and used as a supplementary fuel on site. Whey can also be fermented to produce alcohol.

In addition, there are a number of Cleaner Production opportunities for reducing the loss of product from the process, which include:

- preventing the loss of curds by not overfilling cheese vats;
- completely removing whey and curds from the vats before rinsing;
- segregating all whey drained from the cheese;
- sweeping up pressings instead of washing them to drain;
- screening all liquid streams to collect fines.

Case study 3–3: Recovery of lactose from sweet whey

To reduce the organic load of effluent on its wastewater treatment plant, a New Zealand dairy expanded its whey protein concentrate plant to process all the sweet whey on site and recover all permeate for lactose.

The company increased sweet whey treatment from 1400 m^3/day to 2200 m^3/day. This meant that the quantity of lactose discharged was reduced by 50–70 tonnes, and could be used in making new products.

Although there were some cost savings from reducing the load on the wastewater treatment plant, the most significant economic gain was the income generated from increased production. This was estimated at US$3 million a year.

Case study 3–4: Recovery of cheese solids by installation of screens and settling tanks

An Australian dairy wanted to reduce the amount of cheese solids it discharged to its wastewater treatment plant. To accomplish this, the company installed screens in the cheese room wastewater outlet and built two large settling tanks in the whey room. The settling tanks were intended to remove cheese solids from the process rinse water. Recovered solids could then be reused in the cheese-making process.

The total suspended solids in the effluent decreased significantly and there was a subsequent increase in cheese production of 1%, or 17,700 kg/year. This increased production generated an additional revenue of US$70,000. The total cost of these changes was US$21,000, giving a payback period of less than 4 months.

3.4.2 Cheese packaging

Process description

After maturation cheeses are packed, either as entire cheeses (in the case of small varieties), or in consumer portions for larger cheeses such as cheddar. Packaging usually involves a combination of manual and automated processes. Packaging materials include natural wax, laminated paper/foil, shrink-wrap plastic, cartons and pre-formed plastic boxes.

In some cases it is necessary to clean the surface of the cheese and dry it before packaging. This is most common with cheeses that require a longer maturing time, during which there may be considerable mould growth on the surface. These growths are harmless but not aesthetically pleasing to the consumer.

Cleaning, together with stripping of the cheesecloth bandage, is often a manual process. The process of dividing larger cheeses into smaller portions and then shrink-wrapping them is often a semi-manual operation. Wrapping and boxing of small varieties is normally fully automated. Farmhouse cheddar cheeses, edam, gouda and a few other varieties are often dipped in wax to protect and seal the natural rind.

Inputs and outputs

Figure 3–11 is a flow diagram showing the inputs and outputs for this process.

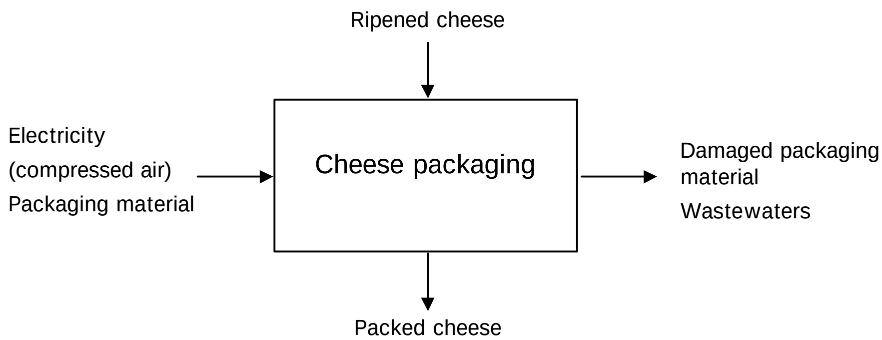

Figure 3–11 Inputs and outputs for cheese packaging

Environmental issues

The major wastes from the cheese packing area are solid wastes, including discarded cuts and small pieces of cheese and damaged packaging material.

In addition there are liquid discharges from the cleaning of packaging machines, work surfaces and conveyors.

Cleaner Production opportunities

All cheese scraps should be collected separately from other waste and either used as raw material for processed cheese manufacturing (where possible) or sold as animal feed.

Liquid wastes should be treated, together with other effluent streams.

3.4.3 Cheese storage

Process description

Cheese storage at the processing plant is limited mainly to the ripening period, as cheeses are normally dispatched for sale immediately after final preparation and packing.

The temperature of storage varies for different types of cheese. Quick-ripening soft cheeses require a low temperature of 4.5°C whereas the harder cheeses, requiring longer ripening periods, are normally stored at up to 18°C.

The most important aspect of cheese storage during the ripening stage is humidity control. Humidity may vary from 75% to 85% for hard, dry-rind cheeses (such as farmhouse cheddar) to over 90% for soft, rindless cheese or surface-ripened soft cheeses.

Inputs and outputs

Figure 3–12 is a flow diagram showing the inputs and outputs from this process.

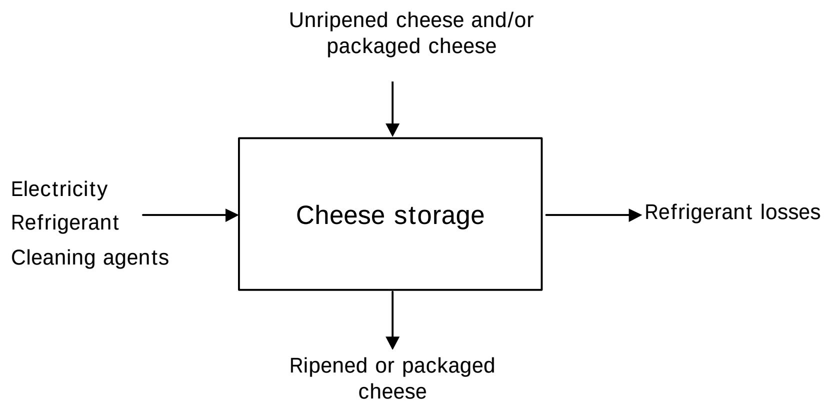

Figure 3–12 Inputs and outputs for cheese storage

Environmental issues

The main environmental issues associated with cheese storage are the energy and refrigerants consumed in refrigerated cold stores.

Cleaner Production opportunities

Methods for reducing energy consumption and minimising the impacts of refrigerant use are:

- installing good insulation;
- keeping doors to cold rooms closed;
- undertaking regular defrosting and maintenance of refrigeration systems;
- avoiding refrigerants that contain CFCs. Refrigeration systems based on ammonia cooling are preferred.

3.5 Evaporated and dried milk production

For many centuries, the only known way to conserve the valuable solids of milk was to manufacture butter and cheese. In the mid-1800s, however, it was found that milk could be preserved by boiling it with sugar to form a thick conserve (sweetened condensed milk) which was protected from spoilage by its high sugar content. This discovery was followed at the end of the century by the development of unsweetened condensed milk. Commonly known as 'evaporated milk', this product was sterilised in the can, using a revolving retort.

The manufacturing of condensed milk products grew steadily until about 1950, but has since declined. The last major markets for these products are in South-east Asia and South America, which are now mainly being supplied by companies that reconstitute skimmed milk powder.

The period of development of the milk conserves coincided with a major development of private and co-operative dairies in the United States, in which butter and cheese were made on a large scale. The skimmed milk resulting from the separation of cream for butter making was, at best, returned to farmers for cattle feed, but was often dumped in rivers and lakes. This practice continued up until the 1930s, at which time it became possible to dry skimmed milk.

Drying of milk was introduced at the beginning of the 20th century on a very small scale, but many years went by before equipment and processes were developed for extensive commercial use in the 1930s. At this time spray drying processes were introduced in parallel with the earlier roller-drying process.

Further development did not take place to any major extent, however, until after the Second World War. During the past 30 years in particular, milk drying has become recognised as an essential link between the dairy farmer and the consuming public. This is because it allows milk to be stored for long periods in times of surplus, and for the powder to be reconstituted or recombined in times of shortage. Extensive research and practical experience in the techniques of recombining have led to the development of a wide range of dairy products. The availability of milk powders has allowed the developed world to help counter the increasing shortage of proteins in many countries. Milk powder is one of the food products most widely used in relief programs.

In the drying process the removal of water takes place in two stages. In the first stage, the milk is concentrated by vacuum evaporation to remove up to 90% of the water, and the second drying stage removes much of the remaining moisture. The reason for this two-stage approach is that the energy required per kilogram of water evaporated in the drying process is up to twenty times as much as that required in the evaporation process.

In order to maximise the effectiveness of the two stages of the process, multiple-effect evaporators with up to six effects and mechanical vapour re-compression, as well as double-stage dryers with energy-saving devices, have been developed. There has been considerable progress in energy efficiency since the major increase in price of fossil fuels that resulted from the energy crisis of 1973.

3.5.1 Evaporation

Process description

Falling film evaporators are the most commonly used evaporators in the dairy industry. They are long, tubular structures made from stainless steel. Milk is introduced at the top of the evaporator and flows as a thin film, down the outside surface of heated tubes or plates, which are packed into the evaporator. The surfaces within the evaporator are heated by steam, which is injected into the top of the evaporator.

In most dairies, multiple-effect evaporation is used, in which a number of evaporators are operated in series. The vapour generated from milk evaporated in the first evaporator is used as the steam input in the next evaporator and so on. Up to seven effects can be operated in series, but three to five is more common. Operating evaporators in this way provides for greater steam efficiency and therefore reduced energy consumption.

In order to attain further steam efficiency, the vapour exiting each evaporator can be recompressed to increase its energy before it is used as the heating medium the subsequent evaporator. Traditionally, thermal recompression, also referred to as thermal vapour recompression (TVR), was the most common recompression system in use. It involved the mixing of high pressure steam with the vapour to compress the mixture to a higher pressure. A single evaporator with a thermocompressor is as efficient as a two-effect unit without one. Therefore thermocompression is often used together with multiple-effect evaporation systems.

The effect on energy efficiency of multiple-effect evaporation and thermal recompression is shown in Table 3–8. TVR evaporators are inexpensive, have no moving parts and provide considerable savings in steam consumption.

Table 3–8 Steam consumption for different evaporation systems [1]

Type of falling film evaporator	**Specific steam consumption** (kg steam/kg water evaporated)	
	Without TVR	With TVR
Two–effect evaporator	0.60	0.25
Five–effect evaporator	0.40	0.20
Seven–effect evaporator	-	0.08

[1] Bylund, 1995

Another form of vapour recompression is mechanical vapour recompression (MVR). MVR evaporators were developed in Switzerland during the Second World War when there was a lack of fuel for raising steam. The pressure increase of the vapour is accomplished by the mechanical energy that drives the compressor.

The advantage of the MVR evaporator is that all of the vapour is recompressed, rather than just a portion of it, as is the case with TVR evaporators. This makes for a high degree of heat recovery. In addition, MVR systems are driven by electricity rather than steam, which means that operating costs are considerably lower. The operating cost of a three-effect MVR evaporator are approximately half that of a conventional seven-effect TVR plant. As a result, it is reasonable to expect that older TVR plants will be replaced with MVR technology.

A disadvantage of MVR systems is that it is not possible to attain high temperatures and thus a steam-heated 'finisher' is required. Furthermore, cleaning of the compressor is difficult, although these problems have been alleviated by the recent introduction of high-volume fans instead of compressors.

It is important to note that another option has become available for pre-concentration of the liquid to be dried. Reverse osmosis (RO), which is a hyper-filtration concentration process, can remove some of the water from the milk mechanically without the application of heat. Electrical power is used to drive pumps, which causes liquid migration through a semi-permeable membrane. However it is only possible to increase the solids concentration to a certain extent. A two fold concentration for milk and whey is common.

Inputs and outputs

Figure 3–13 is a flow diagram showing the inputs and outputs for this process.

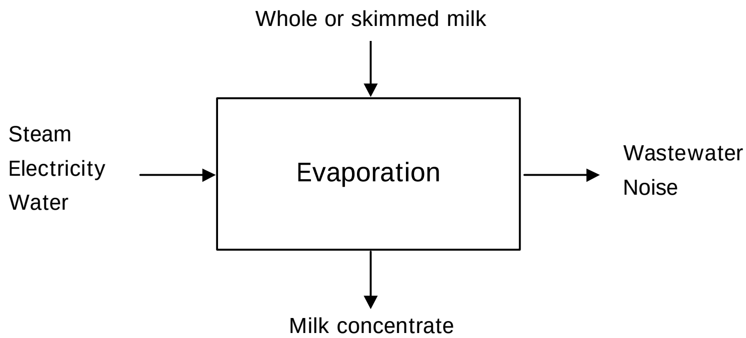

Figure 3–13 Inputs and outputs for evaporation

Environmental issues

The main environmental issue associated with the evaporative concentration of milk is the very high level of energy consumption. For example, milk powder is a highly energy-intensive product.

TVR evaporators generate noise and have high energy consumption, especially if the condensate is not reused. The condensate from an evaporator will normally be sufficiently pure to allow direct disposal. However, it is often used for cleaning instead of hot water and thus the environmental loading is, in theory, very limited.

Contamination of the condensate by milk, through improper adjustments, carryover and backflows, can result in losses of milk solids and pollution of the considerable quantities of water produced during the evaporation process.

Cleaning of MVR compressors is difficult and produces liquid wastes. So, to some extent, does the cleaning of the high-volume fans that have begun to replace mechanical compressors. MVR evaporators use large amounts of electrical energy, which can create a secondary environmental loading.

Cleaner Production opportunities

Cleaner Production opportunities in this area focus on ensuring the efficient operation of the evaporators, including:

- maintaining a liquid level low enough to prevent product boil-over;
- using entrainment separators to avoid carry-over of milk droplets during condensation of evaporated water;
- recirculating low concentration milk and other feedstocks until a required concentration is reached;
- prior to scheduled shut-downs, processing rinse waters with solids content greater than 7% or evaporating them during the next run rather than discharging them to the effluent stream;
- draining equipment thoroughly before starting rinsing and washing;
- collecting the first rinse water for animal feed;
- reducing the frequency of cleaning operations as much as possible;
- reusing condensate as cooling water after circulation through a cooling tower, or as feed water to the boiler.

Case study 3–5: Conversion to mechanical vapour recompression (MVR)

A Japanese dairy upgraded its milk powder process and installed a four-effect MVR evaporator to replace its existing four-effect TVR evaporator. The cost of the new MVR evaporator was US$1.5 million, compared with US$1.3 million for a new TVR evaporator.

At an evaporation rate of 30 tonnes/hour, the annual operating cost of the MVR evaporator was US$680,000, compared with previous annual operating costs of US$175,000 for the TVR evaporator, a saving of nearly 75%. The savings were a result of greatly reduced steam consumption.

When the MVR system was adopted, it was necessary to prevent milk being scorched and contaminating the surfaces of the heat transfer pipes in the evaporator, to maintain design evaporation capacity. As a result, an automated control system was installed to control operating parameters such as flowrate, temperature and pressure.

(CADDET, 1992)

3.5.2 The drying process

Although roller dryers may still be found in the dairy industry and are sometimes useful for specialised products, the use of spray dryers is now almost universal. The trend towards fewer yet larger dairies, coupled with technical advances in drying techniques since the Second World War, and the need for major economies in the use of energy over the past two decades, have made spray dryers the more practical choice. Roller dryers will thus not be discussed other than to say that they have always had severe environmental problems. They generate fine milk flakes in the vapours that are exhausted through a hood and stack placed immediately over the heated rollers and led outside the building. This has necessitated the use of external vapour cleaners.

Process description

After concentration, the milk to be dried is atomised into a fog-like mist, which increases the overall surface area of the milk. The atomised mist is created in a chamber through which high-volume, hot air is being pumped or drawn in a spiral pattern from entry to exit. The milk spray thus evaporates instantly to powder particles. These particles either separate out on the walls and bottom of the chamber due to the cyclonic action or, if they are too fine to react to the centrifugal force, are carried out in the co-current air flow and subsequently collected in smaller cyclones and/or in final fabric filters.

The powder is usually cooled in a fluid bed cooler, especially in areas of high ambient temperatures. This is particularly necessary when powders containing high levels of fat are being dried, to avoid lumping and deterioration of the fat.

Cleaning of the spray tower is normally a dry operation. Wet cleaning should be restricted to a minimum to reduce the risk of bacterial contamination, as moisture is a growth requirement for most bacteria.

Spray drying creates a fire and explosion hazard due to the presence of hot, dry air and a fine, flammable dust. All modern dryers have explosion release mechanisms and fire prevention systems built in.

Inputs and outputs

Figure 3–14 is a flow diagram showing the inputs and outputs for this process.

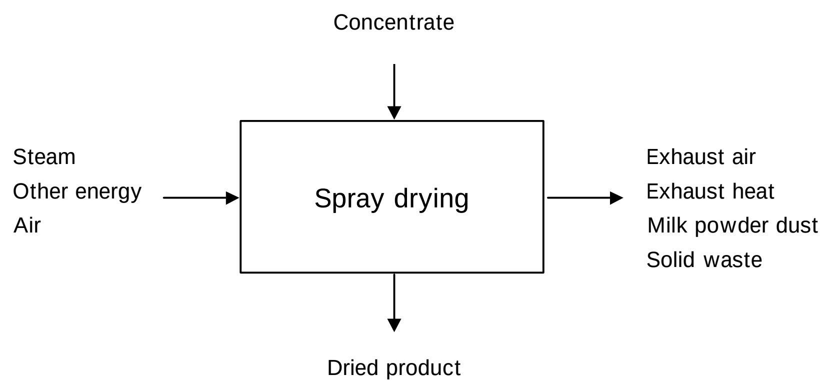

Figure 3–14 Inputs and outputs for the drying process

Environmental issues

A possible source of pollution is the emission of fine milk powder from the air exhaust of drying systems. This can cause acidic deposits on surrounding roofs and open areas.

Cleaner Production opportunities

Methods for avoiding the release of fine milk powder to surrounding areas include:

- minimising emissions to air by using fabric filters or wet scrubbers;
- undertaking wet cleaning only when absolutely necessary, and plan for it to coincide with a change of product;
- controlling air emissions and taking corrective action if levels are beyond acceptable limits.

3.5.3 Packaging and storage of milk powder

Process description

Milk powder is generally packed into bulk containers as soon as it is cool. For export markets and sometimes for domestic markets, milk powders are packaged into coded, multi-layer kraft paper bags with a separately sealed polythene lining, each containing 25 kg of product. The linings are immediately sealed after filling and the bags are then sewn shut.

In order to improve stacking ability and store utilisation, fully sealed bags are generally passed through a bag flattener before being placed on a pallet. Full pallets are often shrink-wrapped to keep the bags clean, improve structural stability, reduce the possibility of theft and make stocktaking easier. Pallets are then transferred to a store, where powders with different codes are usually kept separate.

Inputs and outputs

Figure 3–15 is a flow diagram showing the inputs and outputs for this process.

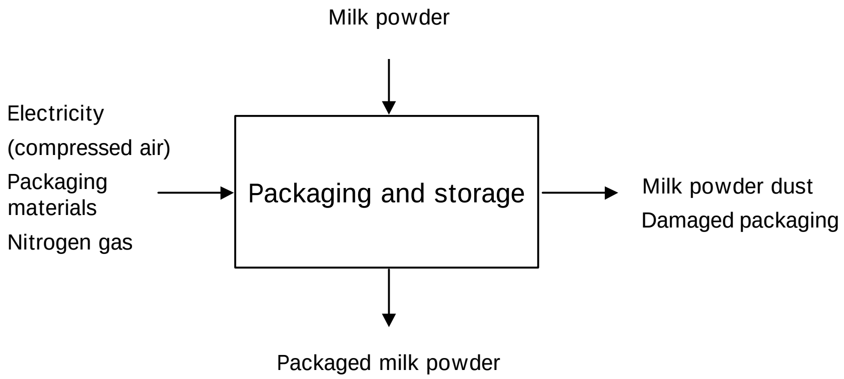

Figure 3–15 Inputs and outputs for packaging and storage of milk powder

Environmental issues

Dust from the exterior surfaces of sacks and/or from sacks that are leaking or not closed properly can deposit on surrounding surfaces. When wet, these deposits become acidic and can cause corrosion.

Cleaner Production opportunities

The Cleaner Production opportunities in this area focus on the prevention of emissions of milk powder dust, including:

- ensuring the proper management of storage operations;
- installing exhaust ventilation to minimise dust in the work place.

3.6 Cleaning

Areas and equipment that are in contact with milk and dairy products must be cleaned regularly to maintain hygiene standards. Furthermore, sanitising must be carried out frequently. The relevant regulatory authority normally defines specific cleaning requirements.

Process description

Production equipment is typically cleaned by pumping rinse water and cleaning solution through all the equipment components. Some equipment has built-in cleaning nozzles that improve the utilisation of the cleaning solution. The cleaning solution that leaves the vessel can be either discharged or pumped to another vessel. With the use of cleaning-in-place (CIP) equipment, however, it is possible to use less clean solution and to recirculate cleaning waters to a significant extent. This allows for savings in both detergent and water.

The design of CIP equipment can vary greatly, from simple systems where a batch of cleaning solutions is prepared and pumped through equipment and then drained, to fully automated plants with tanks for water and cleaning solutions.

Modern CIP systems often involve the use of three tanks: one for hot water rinsing, one for alkaline cleaning solution (caustic soda) and one for acidic rinses (nitric acid). Steam is often used to heat the cleaning solutions. The items of equipment to be cleaned are isolated from product flows and the prepared cleaning solutions are pumped through the vessels and pipes. Simpler CIP systems can consist of only one tank and a pump.

Cleaning cycles are often automated according to set sequences and cleaning times, and usually consist of the following steps:

- rinse with cold water (discharged to sewer);
- addition of detergents and/or caustic soda;
- circulation of cleaning solution through the equipment with turbulent flow to loosen and suspend soils (discharged to sewer);
- rinse with water (discharged to sewer);
- nitric acid rinse to prevent build-up of milk scale (discharged to sewer);
- rinse with water (discharged to sewer).

Inputs and outputs

Figure 3–16 is a flow diagram showing the inputs and outputs for this process.

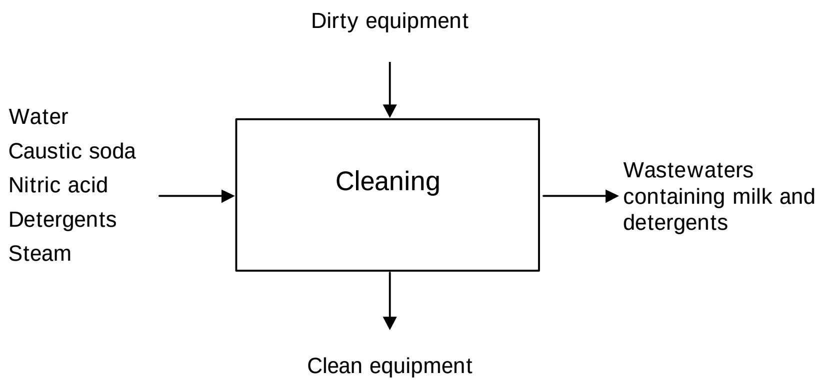

Figure 3–16 Inputs and outputs for cleaning processes

Environmental issues

Cleaning is one of the most water-consuming operations, typically accounting for 25–40% of the total water consumption in a dairy.

The pollution load of cleaning wastewaters is considerable, due to the presence of milk fat and proteins as well as detergents and disinfectants.

Cleaner Production opportunities

For dairies without CIP systems, consideration should be given to their installation. CIP systems make the recovery and reuse of cleaning solutions possible, and systems equipped with in-line monitoring can control the quality of cleaning solutions, thereby maximising the use of detergents and minimising water use. For dairies with CIP equipment, it is important to determine and maintain optimum operational settings to reduce the consumption of both water and detergents.

Further water reductions can be achieved by providing facilities for the collection of final rinse waters so that they can be reused as the initial rinse water in the next CIP cycle.

Detergents and disinfectants can be significant sources of pollution if too much is used. It is very important, therefore, to monitor their consumption. An optimum detergent concentration for cleaning should be determined.

Operators should ensure that tanks, pipes and hoses are as completely empty as possible before they are cleaned. Empty pipelines can be blown with compressed air before cleaning in order to reduce any milk film that may have adhered to the walls of vessels and pipelines.

Cleaning of floors and equipment often consumes large quantities of water, due to the traditional cleaning method in which the operator directs a jet of water from a hose onto equipment and floors until the milk and solids float down the drain. Solid wastes, such as curd particles in the cheese making process, can be collected using a brush or broom rather than being rinsed down the drain.

The use of pigging systems to remove product residues from the internal surfaces of pipeline prior to cleaning can help to reduce the pollutant load of cleaning wastewaters and also allow for product recovery.

Spray nozzles are subject to wear that causes deterioration of the orifice and distortion to the spray pattern. This results in an increased flowrate of water and reduced effectiveness. In general, 10% nozzle wear will result in a 20% increase in water consumption (McNeil and Husband, 1995). Nozzles made from different materials have varying abrasion resistance, as shown in Table 3–9.

Table 3–9 Abrasion wear index for nozzle materials [1]

Material	Abrasion wear index
Brass	1 (poor)
Stainless steel	4-6 (good)
Hard plastic	4-6 (good)
Ceramic	90-200 (excellent)

[1] McNeil and Husband, 1995

Regular monitoring of spray nozzle wear should be incorporated into maintenance programs. Nozzles in service can be compared with new nozzles to determine the extent of wear, and the flowrate of a nozzle can be determined by measuring the time taken to fill a container of known volume.

Case study 3–6: Improved monitoring and operation of CIP equipment

In a Dutch dairy, an analysis of the custard preparation and filling units found that a significant cause of product loss was the cleaning of the pipes and machines. Consequently, monitoring equipment was installed in the cleaning circuits to measure the conductivity and temperature of the rinse waters. The company modified its procedure by installing a level controller, lowering the temperature of the heat exchanger, shortening the cleaning program by 20 minutes, and buying a new software program to monitor the system.

As a result of these changes, consumption of cleaning agents was reduced by 23% and the organic load of effluent discharged to sewer fell significantly. Expenditure on detergents fell by US$28,500/year and effluent charges by US$4200 a year. The capital outlay required for the system was US$3150, so the payback period was only one month.

Case study 3–7: Replacement of nitric and phosphoric acids

An Australian dairy was using a mixture of nitric and phosphoric acids for its CIP operations. The company found that 200 litres of these acids were being used each day, eventually ending up in surface drains. The potential risks to the nearby river motivated the company to look for other cleaning agents.

The company found a new cleaning compound that, when used with caustic soda, virtually eliminated the need for an acid wash. Only 150 litres of the new compound was needed and the wash time was reduced by 25%. The reduction in wash time meant an increase of 1.5 production hours a day. Overall savings from switching cleaning chemicals amounted to US$220 per day.

Case study 3–8: Improved operation procedure in yoghurt production

In a Dutch dairy, rinsing after each batch of yoghurt was resulting in significant product loss and an over-consumption of water. To improve this situation, the dairy modified its process by allowing each batch to drain out and then mixing the remaining product with the next batch. Only 50 litres of 'mixed' product had to be sold as cattle feed, compared to 110 litres ending up as wastewater.

By not rinsing between batches, 12,500 litres of product a year was recovered, resulting in a cost saving of US$4,600. Effluent treatment costs fell by US$2,100 and water charges by US$800. The dairy saved US$7,400 per year with no capital investment or loss of product quality.

3.6.1 Crate washing

Process description

Plastic crates (and to some extent wire crates) are washed in a crate washer. The typical washing sequence is: rinsing with cold and warm water, washing with a washing soda solution, and final rinsing with cold water.

Inputs and outputs

Figure 3–17 is a flow diagram showing the inputs and outputs for this process.

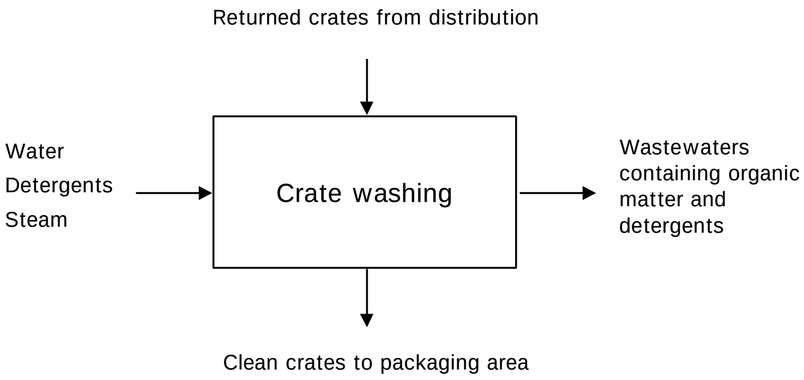

Figure 3–17 Inputs and outputs for crate washer operation

Environmental issues

The crate washer uses large amounts of water and detergents. This causes the discharge of large quantities of water as well as dirt and some organic matter from milk. Leaks often go undetected as the area is generally wet.

Cleaner Production opportunities

Cleaner Production opportunities in this area therefore focus on reducing the consumption of water. Ways of achieving this include:

- optimising water consumption by monitoring the water pressure and the condition of the water spray nozzles;
- installation of spray nozzles of the optimum dimensions;
- fixing leaks promptly;
- turning off the crate washer when not in use;
- recirculating wash water through a holding tank.

3.7 Ancillary operations

3.7.1 Compressed air supply

Process description

Air is compressed in an air compressor and distributed throughout the plant in pressurised pipes. Normally, the compressor is driven by electricity and cooled with water or air.

Inputs and outputs

Figure 3–18 is a flow diagram showing the inputs and outputs for this process.

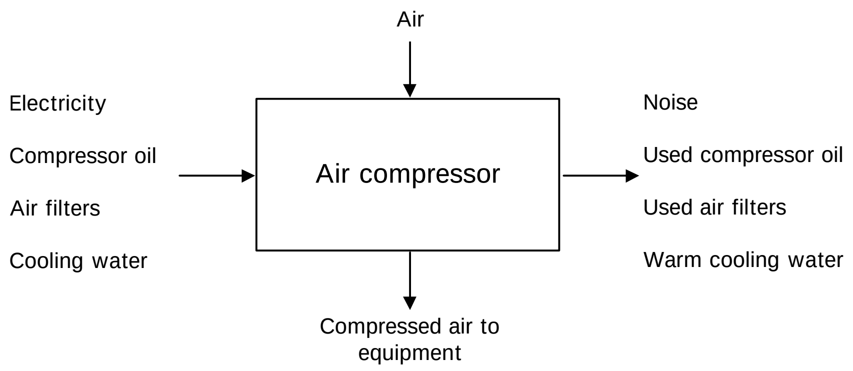

Figure 3–18 Inputs and outputs for production of compressed air

Environmental issues

With just a few small holes in the compressed air system (pipes, valves etc.), a large amount of compressed air is continuously lost. This results in a waste of electricity because the compressor has to run more than is necessary. Table 3–10 lists unnecessary electricity consumption that can be caused by leaks in the compressed air system.

Table 3–10 Electricity loss from compressed air leaks [1]

Hole size (mm)	Air losses (L/s)	kW.h/day	MW.h/year
1	1	6	3
3	19	74	27
5	27	199	73

[1] UNEP, 1996

Air compressors are usually very noisy, causing serious risk of hearing damage to the workers in the area.

If the air compressor is water cooled, water consumption can be quite high.

Cleaner Production opportunities

It is very important to check the compressed air system frequently. The best method is to listen for leaks during periods when there is no production.

Maintenance (e.g. change of compressor oil) and the keeping of accurate log-books will often help identify the onset of system leaks.

A great deal of energy can be saved through these simple measures. It pays to implement procedures that ensure the compressed air system is leak free and well maintained.

The consumption of cooling water should be regulated by a temperature-sensitive valve, ensuring the optimum cooling temperature and minimum use of water. Furthermore, the cooling water can be recirculated via a cooling tower. Alternatively, the cooling water can be reused for other purposes such as cleaning, where the hygiene requirements are low.

Case study 3–9: Reuse of cooling water

An air-cooled system for an air compressor was replaced with a water-cooled one. The water absorbs the heat from the compressor and is then reused in the boilers. Energy is saved in the boilers because the water preheated.

The installation of the water cooling system cost US$18,000 and had a payback period of less than two years.

3.7.2 Steam supply

Process description

Steam is produced in a boiler and distributed throughout the plant by insulated pipes. Condensate is returned to a condensate tank, from where it is recirculated as boiler feed water, unless it is used for heating in the production process.

Inputs and outputs

Figure 3–19 is a flow diagram showing the inputs and outputs for this process.

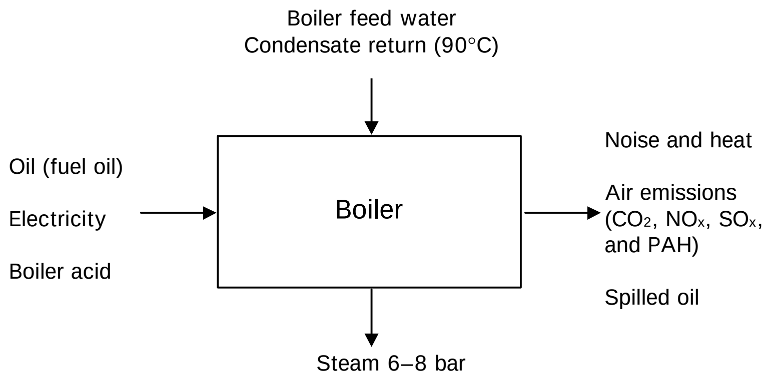

Figure 3–19 Inputs and outputs for supply of steam

The amount and pressure of the steam produced depend on the size of the boiler and how the fuel is injected into the combustion chamber. Other parameters include pressure level, fuel type, and maintenance and operation of the boiler.

Environmental issues

Inefficiencies in boiler operation of boilers and steam leaks leads to the waste of valuable fuel resources as well as additional operating costs.

Combustion of fuel oil results in emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and polycyclic aromatic hydrocarbons (PAHs). Some fuel oils contain 3–5% sulphur and result in sulphur dioxide emissions of 50–85 kg per 1000 litres of fuel oil.

Sulphur dioxide converts to sulfuric acid in the atmosphere, resulting in the formation of acid rain. Nitrogen oxides contribute to smog and can cause lung irritation.

If the combustion is not adjusted properly, and if the air:oil ratio is too low, there are high emissions of soot from the burners. Soot regularly contains PAHs that are carcinogenic.

Table 3–11 shows the emissions produced from the combustion of various fuels to produce steam.

Table 3–11 Emissions from the combustion of fuel oil

Input		**Outputs**	
Fuel oil (1% sulphur)	1 kg	Energy content	11.5 kW.h
		Carbon dioxide (CO_2)	3.5 kg
		Nitrogen oxides (NO_x)	0.01 kg
		Sulphur dioxide (SO_2)	0.02 kg

1 kg of oil = 1.16 litre of oil (0.86 kg/L)

1 kW.h = 3.6 MJ

Oil is often spilt in storage and at the boiler. If the spilt oil is not collected and reused or sold, it can cause serious pollution of soil and water.

Cleaner Production opportunities

Instead of using fuel oil with a high sulphur content, it is advantageous to change to a fuel oil with a low sulphur content (less than 1%). This increases the efficiency of the boiler and reduces sulphur dioxide emissions. There are no investment costs involved, but the running costs will be higher because fuel oil with a lower sulphur content is more expensive.

It is essential to avoid oil spills and, if they occur, to clean them up properly and either reuse or sell the oil. A procedure for handling oil and oil spills should be instituted and followed.

If the boiler is old, installation of a new boiler should be considered. Making the change from coal to oil, or from oil to natural gas, should also be considered. In some burners is it possible to install an oil atomiser and thereby increase efficiency. Both options (new boiler and atomiser) will often pay back the investment within 5 years. The actual payback period depends on the efficiency of the existing boiler, the utilisation of the new boiler, the cost of fuel, and other factors.

Steam leaks should be repaired as soon as possible when identified. Even small steam leaks cause substantial losses of steam and corresponding losses of oil and money.

Insulation of hot surfaces is a cheap and very effective way of reducing energy consumption. The following equipment is often not insulated:

- valves, flanges;
- scalding vats/tanks;
- autoclaves;
- cooking vats;
- pipe connections to machinery.

Through proper insulation of this equipment, heat losses can be reduced by 90%. Often the payback period for insulation is less than 3 years.

If steam condensate from some areas is not returned to the boiler, both energy and water are wasted. Piping systems for returning condensate to the boiler should be installed to reduce energy losses. The payback period is short, because 1 m^3 of lost condensate represents 8.7 kg of oil at a condensate temperature of 100 C.

The efficiency of boilers depends on how they are operated. If the air to fuel ratio is wrongly adjusted incineration will be poor, causing more pollution and/or poorer utilisation of the fuel. Proper operation of the boiler requires proper training of employees and, if the expertise not is available within the company, frequent visits of specialists.

Case study 3–10: Poorly operated coal-fired boiler

Samples of coal and waste ash were taken from coal-fired boilers and were measured for specific energy (kJ/kg), ash percentage and moisture percentage. Results showed that up to 29% of the total fuel supply was not being combusted in the boilers, with the least efficient boiler generating an additional 230 kg of unburnt material per tonne of coal. This unburnt material was retained in the ash and disposed of in landfill.

To improve performance, the company trained employees in efficient boiler operations, so that boilers could be run on automatic control. After this training boiler efficiency increased by 25%, and the specific energy fell to 6 kJ/kg.

Coal use has been reduced by 1500 tons, making an annual saving of US$45,000. Improved boiler operation has also reduced annual landfill disposal by 275 tonnes. The company has hired a specialist company to monitor boiler efficiency on an ongoing basis. The cost of this service is US$2100 per month.

3.1.3 Water supply

Process description

High-quality domestic water supplies may not need any treatment before use in the plant. However if the available water is of poor quality it may be necessary to treat it to meet hygiene requirements. Treatment normally consists of aeration and filtration through gravel or sand and chlorination may also be necessary.

Figure 3–20 is a flow diagram showing the inputs and outputs from this process.

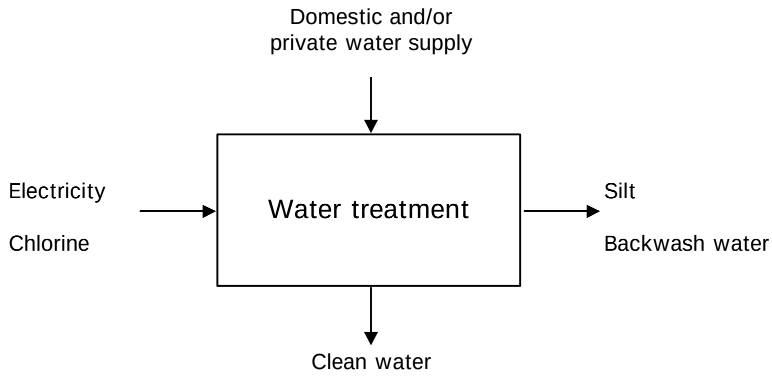

Figure 3–20 Inputs and outputs for water treatment

Environmental issues

Water is a valuable resource, so its use should be minimised wherever possible. Since electricity is needed for pumping water, energy consumption also increases with increasing water consumption.

The losses that occur due to holes in water pipes and running taps can be considerable. Table 3–12 shows the relationship between size of leaks and water loss.

Table 3–12 Water loss from leaks at 4.5 bar pressure [1]

Hole size (mm)	**Water loss** (m^3/day)	**Water loss** (m^3/year)
0.5	0.4	140
1	1.2	430
2	3.7	1300
4	18	6400
6	47	17,000

[1] UNEP, 1996.

Cleaner Production opportunities

To ensure that water consumption is optimised, consumption should be monitored on a regular basis. It is helpful to install water meters for separate departments and even for individual processes or pieces of equipment. Whether this is feasible depends on the level of water consumption and the expected savings in each instance. Water consumption can be reduced by 10–50% simply by increasing employees' awareness and by educating them on how to reduce unnecessary consumption.

Energy-efficient pumps should be installed to reduce the energy consumed for pumping of water. New and efficient pumps can reduce energy consumption by up to 50% compared with standard pumps. It is very important to select a pump with optimum pumping capacity and position it close to the required pump work.

3.1.4 Refrigeration and cooling

Process description

In refrigeration and cooling systems a refrigerant, typically ammonia or a chlorofluorocarbon (CFC)-based substance, is compressed, and its subsequent expansion is used to chill a closed circuit cooling system. The refrigerant itself can act as a primary coolant, recirculated directly through the cooling system, or alternatively, it can be used to chill a secondary coolant, typically brine or glycol.

CFCs were once extensively used in refrigeration systems, but they are now prohibited in most countries, and their use is being phased out as a result of the Montreal Protocol on ozone-depleting substances. All cooling systems should be closed circuit systems and free of leaks. However, due to wear and tear and inadequate maintenance, leaks may occur.

Inputs and outputs

Figure 3–21 is a flow diagram showing the inputs and outputs from this process.

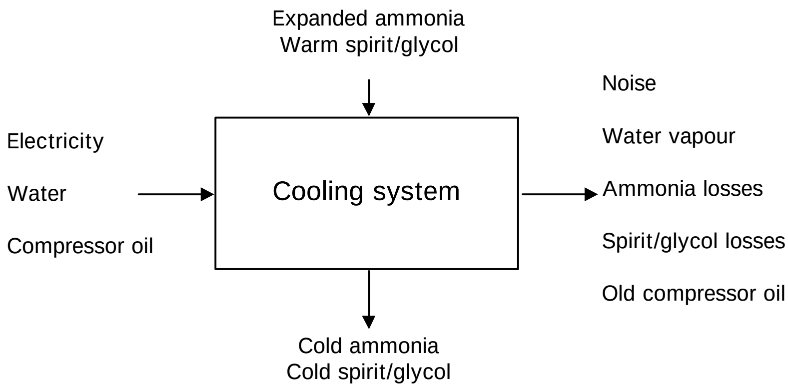

Figure 3–21 Inputs and outputs for cooling system

Environmental issues

The consumption of electricity and of water can be quite high.

If CFC-based refrigerants are used there is a risk that refrigerant gases will be emitted to the atmosphere, contributing to the depletion of the ozone layer. There is also a risk of ammonia and glycol leaks, which can be an occupational, health and safety problem for workers, but can also result in environmental problems.

Cleaner Production opportunities

CFC-based refrigerants should be replaced by the less hazardous hydrogenated chlorofluorocarbons (HCFCs) or, preferably, by ammonia. In the long run both CFCs and HCFCs should be replaced by other refrigerants according to the Montreal Protocol. Replacing CFCs can be expensive, as it may require the installation of new cooling equipment.

Minimising the ingress of heat into refrigerated areas can reduce energy consumption. This can be accomplished by insulating cold rooms and pipes that contain refrigerant, by closing doors and windows to cold areas, or by installing self-closing doors.

If water and electricity consumption in the cooling towers seems high, it could be due to algal growth on the evaporator pipes. Another reason could be that the fans are running at too high a speed, blowing the water off the cooling tower. Optimising the running of the cooling tower can save a lot of water.

4 CLEANER PRODUCTION CASE STUDY

This chapter contains a case study of a Cleaner Production assessment carried out at a dairy in The Netherlands. The case study provides an example of how to carry out a Cleaner Production assessment at a dairy as well as some specific Cleaner Production opportunities that have proved successful.

4.1 Campina Melkunie Maasdam

The Cleaner Production assessment for this Dutch company was carried out as part of the PRISMA project (Dutch Ministry of Economic Affairs, 1991). The project identified five Cleaner Production opportunities:

- better emptying of production tanks;
- elimination of rinsing between yogurt batches;
- reduced rinsing at product change-over;
- optimisation of cleaning operations;
- recovery of low-grade heat.

This case study demonstrates that even when considerable effort has already been made to improve the environmental performance of a company, it may still be possible to identify additional Cleaner Production opportunities through a formal Cleaner Production assessment process.

4.1.1 Company description

Campina Melkunie Maasdam is part of the Campina Melkunie Holland co-operative. The company employs 170 people, who work two shifts. The company produces a wide range of milk, custard and yogurt products. In total l05 million litres of milk is processed per year; 92 million litres for market milk and 13 million litres for other dairy products.

4.1.2 Process description

The milk is delivered to the plant in milk tankers, after which it is separated. Depending on the required end product, the milk may then be mixed with non-separated milk to obtain the correct fat content. The milk is pasteurised and homogenised, and packed into cardboard or glass packaging. A proportion of the milk is processed further into yogurt, custard and buttermilk.

During the production process, product clings to the internal surfaces of pipes and equipment, which can lead to reduced product quality. To avoid this, the entire process is cleaned and sanitised after each production day, and specific pieces of equipment may also be cleaned throughout a production day. Cleaning agents containing, among other things, sodium hydroxide, hydrogen peroxide and peracetic acid are commonly used.

4.1.3 Environmental aspects

Liquid effluent

Like all dairy processing plants, the company generates a warm, liquid effluent stream containing milk constituents and cleaning and sanitising agents. The quantity of effluent discharged per year is 130,000 L. The organic loading of this wastewater averages about 1240 mg COD/L, which is equivalent to 3600 pollution units (pu), where 1 pu equals the organic pollution load generated by one person. The company is not connected to a wastewater treatment plant and therefore discharges treated effluent directly to surface water.

The cost for discharging effluent is calculated according to the Dutch Pollution of Surface Water Act and amounts to US$120,000 per year, based on US$33 per pu.

Emissions to air

Emissions to air principally result from the combustion of fossil fuels in the boiler for steam generation. Pollutants emitted include NO_x, CO, CO_2 and PAHs, but the quantities have not been measured.

Chemical waste

The company has three chemical waste streams: ink, solvents and laboratory waste. About 10 litres per year of each of these wastes are generated. This is taken away to the small municipal chemical waste depot.

Solid wastes

By far the largest proportion of the company's solid waste stream is of packaging materials, particularly the cardboard containers used to package milk. Approximately 125,000 containers are lost as waste per year, which represents approximately 0.25% of the total number of cartons consumed. The value of this waste stream has been estimated to be about US$6000. Paper wastes are reused off site wherever possible and reject glass bottles are also recycled off site.

Energy

The company generates its own steam in an on-site boiler for heating and processing, and other energy needs are met using electricity.

Previous environmental initiatives

Prior to the PRISMA project waste prevention measures had already been taken by the company, driven by financial and efficiency considerations. A lot of energy was used for the production of milk products. With the high energy prices of the 1970s it was cost-effective to take energy-saving measures. A lot of water was also used. For the production of 1 litre of milk ten years ago, 10 litres of water were needed. This has since been reduced to 1.4 litres of water.

The preventive measures taken primarily involved reuse options, such as using the cooling and rinse water several times before discharging it. Another measure, to reduce the effluent charge, is to return waste product to the production process or collect it separately and take it away as cattle feed. Only if this is not possible is the product discharged.

4.1.4 The Cleaner Production assessment

Based on previous studies of product losses undertaken by the company, it was possible to identify areas where relatively large amounts of waste and emissions were being produced.

The primary sources of pollution load are product loss to the effluent stream and the use of cleaning agents. This is caused by, among other things, batch production processes, which lead to the need for frequent cleaning and subsequent losses during start-up and shut-down.

Another area of concern was the high energy consumption for heating and cooling.

To reduce the pollution load fourteen preventative measures were drawn up. Since then, eight of them have been implemented. Three options still have to be looked at more closely and three have been found to be impracticable for various reasons.

The result has been as follows:

- a reduction in product loss by 24,000 litres (3.4% reduction);
- a 23% saving in consumption of chemicals;
- a reduction in pollution load by 198 pu./yr (a 5.5% reduction);
- a 138,000 m^3/yr saving in natural gas consumption.

Total savings have amounted to US$68,000 per year, and possibly an additional US$26,000 in reduced effluent charges. This was achieved by a single investment of US$32,000.

Table 4–1 Identified Cleaner Production options

	Projects implemented	**Projects still to be implemented**	**Feasibility study required**
Loss of product	Improvements to procedures Improvements to tank emptying practices	Replacement of cooling installation	
Cleaning operations	No rinsing between yogurt batches Optimisation of cleansing process Reduced rinsing		Substitution of cleansing agents Reuse of sour products
Energy	Pre-heating milk for buttermilk Custard heating	Pre-heating milk for yogurt production	
Miscellaneous	Replacement of ink injector		

4.1.5 Better emptying of the production tanks

The filling of packaging containers with product at the plant is a batch process. At the end of each batch, residual product remains in processing vessel. Previous to the Cleaner Production project, this residual product was discharged to sewer with the effluent stream. Now the residual product remaining in the processing vessel is collected and returned to the production process or taken away as cattle feed.

This measure has reduced the amount of product lost to the wastewater stream by 11,500 litres, which represents a 1.6% reduction in the total product loss, and a decrease in the discharge of organic matter of 31 pu/yr.

Implementing this measure was a simple matter. A milk can is positioned below the drain point of the processing vessel. After collecting residual product, the can is emptied into one of the production vessels or into the cattle feed tank, depending on the type of product.

The value of the product recovered is US$4850 and reduction in effluent discharge came to about US$1150. The total annual savings have been US$6000 per year and there was no initial capital cost.

4.1.6 Avoidance of rinsing between yogurt batches

Rinsing traditionally took place between different batches of yogurt to prevent the mixing of different products. Each rinsing incurred a product loss of 110 litres. Most of the rinse water was used as animal feed, with the residual discharged to sewer. The total product loss per year amounted to 22,880 litres, and the total volume of rinse water used was 2,500 m^3 per year.

The new procedure employed for product changeover was to let the processing vessel drain of yogurt and then allow the next batch of yogurt into the system. The resulting mixed zone is collected and used as animal feed. As a result, it is no longer necessary to rinse between the two batches.

Investigations undertaken as part of the Cleaner Production project showed that product loss is reduced by 60 litres per batch, or a total of 12,500 litres per year. The new procedure has also led to a 2,500 m^3 per year reduction in water consumption, because rinsing between batches is no longer undertaken. In addition, the time required to empty the filling machine and collect the mixed zone takes one hour less than the previous rinsing procedure. The emptying of the filling machine demands extra attention from the operators and so written work instructions were prepared.

The annual savings resulting from the change have been US$4600 in product costs, US$2100 in effluent discharge costs and US$7400 in water consumption.

4.1.7 Reduced rinsing at product change-over

Rinsing of process equipment is undertaken between batches of sweet and sour products and between dark and light coloured products. This is done by passing 2000 litres of water through the system eight times in succession. Instead of using eight successive rinses to remove residual product, six rinses were found to be sufficient. This measure has reduced water consumption by 4 m^3 per rinse, which amount to 3120 m^3 per year.

No capital expenditure was required and there were no technical complications and savings amounted to US$2450 per year.

4.1.8 Optimisation of cleansing operations

Analysis of the custard preparation and filling operations showed that the cleaning of pipelines and equipment was an area of significant product loss.

A trial was undertaken as part of the project demonstrated that cleaning procedures were far from optimal. Measuring devices were installed in the feed and return lines of the cleansing circuit to measure the temperature and conductivity of the rinse waters. The consumption of detergents and sanitising agents before and after the trial were also measured. Based on the findings of the trial the following changes were made to the cleaning cycle:

- level controllers were installed on the mixing vessel to control the volume of cleaning water supplied to the vessel;
- the output temperature of one of the heat exchanger was lowered to reduce the temperature of cleaning water;
- a software program was installed to better control the cleaning program;
- the cleaning time was reduced by 20 minutes.

As a result of the changes, the consumption of detergents and sanitising agents reduced by 23% and the organic load of the wastewater discharged from the cleaning process reduced by 110 pu.

The annual savings resulting from the change have been US$28,500 in detergent costs and US$4200 in effluent discharge costs and US$7400 in water consumption. The only capital cost incurred was for the installation of the measuring equipment, which was US$3150. Therefore the payback on the project has been approximately one month.

4.1.9 Recovery of low-grade heat

One of the steps in the production process requires the heating of product to 90°C. The company previously used steam from the on-site, natural gas boiler. The company changed their process to utilise low-grade heat from the cooling water system.

Heat recovered from the return leg of the cooling water system was used to the heat the product up to 30°C. Steam from the boiler was then used to heat the product the rest of the way, up to 90°C. As a result, 54,000 m^3 less natural gas was used.

The capital investment required for the process changes was US$15,800 and the resulting savings in natural gas costs came to US$7900 per year. Therefore the payback period for the project was 2 years.

4.1.10 Contacts

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5 CLEANER PRODUCTION ASSESSMENT

A Cleaner Production assessment is a methodology for identifying areas of inefficient use of resources and poor management of wastes, by focusing on the environmental aspects and thus the impacts of industrial processes.

Many organisations have produced manuals describing Cleaner Production assessment methodologies at varying levels of detail. However, the underlying strategies are much the same. The basic concept centres around a review of a company and its production processes in order to identify areas where resource consumption, hazardous materials and waste generation can be reduced. Table 5-1 lists some of the steps described in the more well-known methodologies.

Table 5-1 Methodologies for undertaking a Cleaner Production assessment

Organisation	**Document**	Methodology
UNEP, 1996	*Guidance Materials for the UNIDO/UNEP National Cleaner Production Centres*	1. Planning and organisation 2. Pre-assessment 3. Assessment 4. Evaluation and feasibility study 5. Implementation and continuation
UNEP, 1991	*Audit and Reduction Manual for Industrial Emissions and Wastes. Technical Report Series No. 7*	1. Pre-assessment 2. Material balance 3. Synthesis
Dutch Ministry of Economic Affairs, 1991	*PREPARE Manual for the Prevention of Waste and Emissions*	1. Planning and organisation 2. Assessment 3. Feasibility 4. Implementation
USEPA, 1992	*Facility Pollution Prevention Guide*	1. Development of pollution prevention programme 2. Preliminary assessment

The rest of this chapter describes the steps within a Cleaner Production assessment as outlined in the UNEP/UNIDO document, *Guidance Materials for UNIDO/UNEP National Cleaner Production Centres*. (UNEP, 1995). The steps from this methodology are detailed further in Figure 5—1.

See section 5.1

Phase I: Planning and organisation

- Obtain management commitment
- Establish a project team
- Develop policy, objectives and targets
- Plan the Cleaner Production assessment

↓

See section 5.2

Phase II: Pre-assessment (qualitative review)

- Company description and flow chart
- Walk-through inspection
- Establish a focus

↓

See section 5.3

Phase III: Assessment (quantitative review)

- Collection of quantitative data
- Material balance
- Identify Cleaner Production opportunities
- Record and sort options

↓

See section 5.4

Phase IV: Evaluation and feasibility study

- Preliminary evaluation
- Technical evaluation
- Economic evaluation
- Environmental evaluation
- Select viable options

↓

See section 5.5

Phase V: Implementation and continuation

- Prepare an implementation plan
- Implement selected options
- Monitor performance
- Sustain Cleaner Production activities

Figure 5—1 Overview of the Cleaner Production assessment methodology *(UNEP, 1996)*

5.1 Planning and organisation

The objective of this phase is to obtain commitment to the project, initiate systems, allocate resources and plan the details of the work to come. A project has more chance of success if this groundwork is done well.

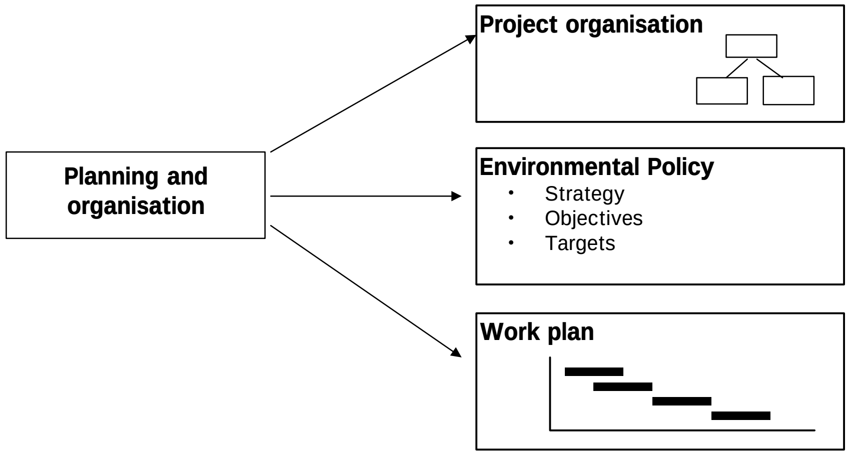

Figure 5—2 Planning and organisation phase

5.1.1 Obtain management commitment

Experience from companies throughout the world shows that Cleaner Production results in both environmental improvements and better economic performance. However, this message has to reach the management of the company. Without management commitment the Cleaner Production assessment may be only a short-term environmental management tool.

5.1.2 Establish a project team

It is best to establish a project team as early in the process as possible. The project team is responsible for progressing the assessment and will normally undertake the following tasks:

- analysis and review of present practices (knowledge);
- development and evaluation of proposed Cleaner Production initiatives (creativity);
- implementation and maintenance of agreed changes (authority).

5.1.3 Develop environmental policy, objectives and targets

The environmental policy outlines the guiding principles for the assessment. It acts to focus efforts in a way considered most important by management. The environmental policy can be refined as the project team gains more insight into the Cleaner Production possibilities within the company.

The policy contains the company's mission and vision for continuous environmental improvement and compliance with legislation. Objectives describe how the company will do this. For example, objectives could include reducing consumption of materials and minimising the generation of waste. Targets are measurable and scheduled, and are used to monitor if the company is proceeding as planned. An example of a target might be a 20% reduction in electricity consumption within 2 years.

In general, objectives and targets should be:

- acceptable to those who work to achieve them;
- flexible and adaptable to changing requirements;
- measurable over time (targets only);
- motivational;
- in line with the overall policy statement.

5.1.4 Plan the Cleaner Production assessment

The project team should draw up a detailed work plan and a time schedule for activities within the Cleaner Production assessment. Responsibilities should be allocated for each task so that staff involved in the project understand clearly what they have to do. It is also wise to anticipate any problems or delays that may arise and plan for them accordingly. Lengthy delays and problems arising out of poor planning erode motivation at both the worker and management level.

5.2 Pre-assessment

The objective of the pre-assessment is to obtain an overview of the company's production and environmental aspects. Production processes are best represented by a flow chart showing inputs, outputs and environmental problem areas.

5.2.1 Company description and flow chart

A description of the company's processes should answer the following questions:

- What does the company produce?
- What is the history of the company?
- How is the company organised?
- What are the main processes?
- What are the most important inputs and outputs?

Processes which take place as part of the company's activities can be represented using a detailed process flow chart. Flow chart production is a key step in the assessment and forms the basis for material and energy balances which occur later in the assessment. Process flow charts should pay particular attention to activities which are often neglected in traditional process flow charts, such as:

- cleaning;
- materials storage and handling;
- ancillary operations (cooling, steam and compressed air production);
- equipment maintenance and repair;
- materials that are not easily recognisable in output streams (catalysts, lubricants etc.);
- by-products released to the environment as fugitive emissions.

The process flow chart is meant of providing an overview and should thus be accompanied by individual input/output sheets for each unit operation or department. Figure 5—3 provides an example of an input/output worksheet, however it may be arranged in various ways.

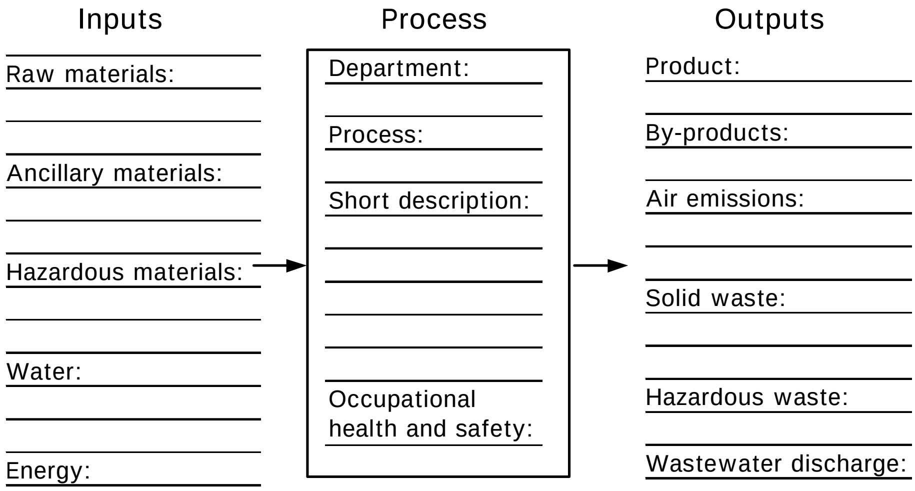

Figure 5—3 Example of an input/output worksheet

5.2.2 Walk-through inspection

Much of the information needed to fill out the input/output sheets, described above, may be obtained during a walk-through inspection of the company.

The walk-through inspection should, if possible, follow the process from the start to the finish, focusing on areas where products, wastes and emissions are generated. During the walk-through, it is important to talk to the operators, since they often have ideas or information that can be useful in identifying sources of waste and Cleaner Production opportunities. The text box over page provides examples of the types of questions that may be asked to prompt the investigation.

During the walk-through problems encountered along the way should be listed, and if there are obvious solutions to these they should also be noted. Special attention should be paid to no-cost and low-cost solutions. These should be implemented immediately, without waiting for a detailed feasibility analysis.

5.2.3 Establish a focus

The last step of the pre-assessment phase is to establish a focus for further work. In an ideal world, all processes and unit operations should be assessed. However time and resource constraints may make it necessary to select the most important aspect or process area. It is common for Cleaner Production assessments to focus on those processes that:

- generate a large quantity of waste and emissions;
- use or produce hazardous chemicals and materials;
- entail a high financial loss;
- have numerous obvious Cleaner Production benefits;
- are considered to be a problem by everyone involved.

All the information collected during the pre-assessment phase should be well organised so that it is easily accessed and updated.

Questions to be answered during a walk-through inspection

Are there signs of poor housekeeping (untidy or obstructed work areas etc.)?

Are there noticeable spills or leaks? Is there any evidence of past spills, such as discoloration or corrosion on walls, work surfaces, ceilings and walls, or pipes?

Are water taps dripping or left running?

Are there any signs of smoke, dirt or fumes to indicate material losses?

Are there any strange odours or emissions that cause irritation to eyes, nose or throat?

Is the noise level high?

Are there open containers, stacked drums, or other indicators of poor storage procedures?

Are all containers labelled with their contents and hazards?

Have you noticed any waste and emissions being generated from process equipment (dripping water, steam, evaporation)?

Do employees have any comments about the sources of waste and emissions in the company?

Is emergency equipment (fire extinguishers etc.) available and visible to ensure rapid response to a fire, spill or other incident?

5.3 Assessment

The aim of the assessment phase is to collect data and evaluate the environmental performance and production efficiency of the company. Data collected about management activities can be used to monitor and control overall process efficiency, set targets and calculate monthly or yearly indicators. Data collected about operational activities can be used to evaluate the performance of a specific process.

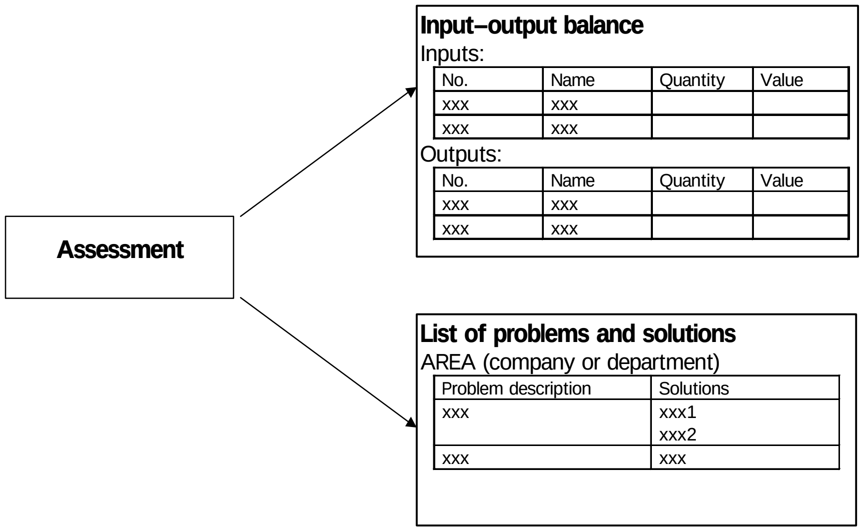

Figure 5—4 Assessment phase

5.3.1 Collection of quantitative data

It is important to collect data on the quantities of resources consumed and wastes and emissions generated. Data should be represented based on the scale of production: for example: water consumption per tonne of live carcass weight (LCW) processed or mass of organic matter (COD) generated per tonne of live carcass weight (LCW) processed. Collection and evaluation of data will most likely reveal losses. For instance, high electricity consumption outside production time may indicate leaking compressors or malfunctioning cooling systems.

In determining what data to collect, use the input/output worksheets, described previously, as a guide. Most data will already be available within the company recording systems, e.g. stock records, accounts, purchase receipts, waste disposal receipts and the production data. Where information is not available, estimates or direct measurements will be required.

5.3.2 Material balance

The purpose of undertaking a material balance is to account for the consumption of raw materials and services that are consumed by the process, and the losses, wastes and emissions resulting from the process. A material balance is based on the principle of 'what comes into a plant or process must equal what comes out'. Ideally inputs should equal outputs, but in practice this is rarely the case, and some judgment is required to determine what level of accuracy is acceptable.

A material balance makes it possible to identify and quantify previously unknown losses, wastes or emissions, and provide an indication of their sources and causes. Material balances are easier, more meaningful and more accurate when they are undertaken for individual unit operation. An overall company-wide material balance can then be constructed with these.

The material balance can also be used to identify the costs associated with inputs, outputs and identified losses. It is often found that presenting these costs to management can result in a speedy implementation of Cleaner Production options.

While it is not possible to lay down a precise and complete methodology for undertaking a material balance, the following guidelines may be useful:

- Prepare a process flow chart for the entire process, showing as many inputs and outputs as possible.
- Sub-divide the total process into unit operations. (Sub-division of unit operations should occur in such a way that there is the smallest possible number of streams entering and leaving the process).
- Do not spend a lot of time and rescues trying to achieve a perfect material balance; even a preliminary material balance can reveal plenty of Cleaner Production opportunities.

Environmental performance indicators for the process can be developed from the material balance data. This is achieved by dividing the quantity of a material input or waste stream by the production over the same period. Performance indicators may be used to identify over-consumption of resources or excessive waste generation by comparing them with those of other companies or figures quoted in the literature. They also help the company track its performance towards its environmental targets.

5.3.3 Identify Cleaner Production opportunities

Identifying Cleaner Production opportunities depends on the knowledge and creativity of the project team members and company staff, much of which comes from their experience. Many Cleaner Production solution are arrived at by carefully analysing the cause of a problem.

Another way of identifying Cleaner Production opportunities is to hold a 'brainstorming' session, where people from different parts of the organisation meet to discuss solutions to specific problems in an open and non-threatening environment.

Some other sources of help from outside the organisation could be:

- this guide;
- external industry personnel or consultants;
- trade associations;
- universities, innovation centres, research institutions, government agencies;
- equipment suppliers;
- information centres, such as UNEP or UNIDO;
- literature and electronic databases.

5.3.4 Record and sort options

Once a number of Cleaner Production opportunities have been suggested and recorded, they should be sorted into those that can be implemented directly and those that require further investigation.

It is helpful to follow the following steps:

- Organise the options according to unit operations or process areas, or according to inputs/outputs categories (e.g. problems that cause high water consumption).
- Identify any mutually interfering options, since implementation of one option may affect the other.
- Opportunities that are cost free or low cost, that do not require an extensive feasibility study, or that are relatively easy to implement, should be implemented immediately.
- Opportunities that are obviously unfeasible, or cannot be implemented should be eliminated from the list of options for further study.

Table 5—2 Example of information recorded for identified options

Problem type	**Problem description**	**Cleaner Production options**
Examples: • resource consumption • energy consumption • air pollution • solid waste • wastewater • hazardous waste • occupational health and safety	Examples: • name of process and department • short background of problem • amount of materials lost or concentration of pollutants • money lost due to lost resources	Examples: • how the problem can be solved • short-term solution • long-term solution • estimated reductions in resource consumption and waste generation

5.4 Evaluation and feasibility study

The objective of the evaluation and feasibility study phase is to evaluate the proposed Cleaner Production opportunities and to select those suitable for implementation.

The opportunities selected during the assessment phase should all be evaluated according to their technical, economic and environmental merit. However, the depth of the study depends on the type of project. Complex projects naturally require more thought than simple projects. For some options, it may be necessary to collect considerably more information. An important source of this information may be employees affected by the implementation.

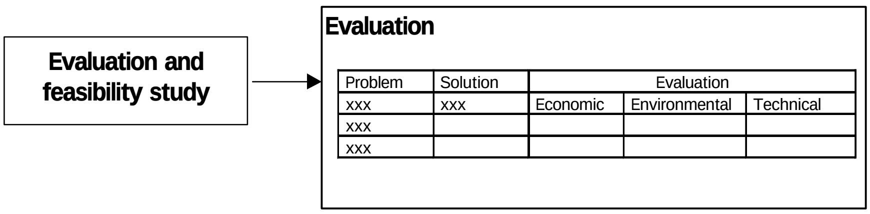

Figure 5—5 Evaluation and feasibility study phase

5.4.1 Preliminary evaluation

The quickest and easiest method of evaluating the different options is to form a group, consisting of the project team and management personnel, and discuss the possible solutions one by one. This process should give a good indication of which projects are feasible and what further information is required.

5.4.2 Technical evaluation

The potential impacts on products, production processes and safety from the proposed changes need to be evaluated before complex and costly projects can be decided upon. In addition, laboratory testing or trial runs may be required when options significantly change existing practices. A technical evaluation will determine whether the opportunity requires staff changes or additional training or maintenance.

5.4.3 Economic evaluation

The objective of this step is to evaluate the cost effectiveness of the Cleaner Production opportunities. Economic viability is often the key parameter that determines whether or not an opportunity will be implemented.

When performing the economic evaluation, costs of the change are weighed against the savings that may result. Costs can be broken into capital investments and operating costs. Standard measures used to evaluate the economic feasibility of a project are payback period, net present value (NPV), or internal rate of return (IRR).

Capital investment is the sum of the fixed capital costs of design, equipment purchase, installation and commissioning, costs of working capital, licenses, training, and financing. Operating costs, if different to existing conditions will need to be calculated. It may be that operating costs reduce as a result of the change, in which case, these should be accounted for in the evaluation as an ongoing saving.

5.4.4 Environmental evaluation

The objective of the environmental evaluation is to determine the positive and negative environmental impacts of the option. In many cases the environmental advantages are obvious: a net reduction in toxicity and/or quantity of wastes or emissions. In other cases it may be necessary to evaluate whether, for example, an increase in electricity consumption would outweigh the environmental advantages of reducing the consumption of materials.

For a good environmental evaluation, the following information is needed:

- changes in amount and toxicity of wastes or emissions;
- changes in energy consumption;
- changes in material consumption;
- changes in degradability of the wastes or emissions;
- changes in the extent to which renewable raw materials are used;
- changes in the reusability of waste streams and emissions;
- changes in the environmental impacts of the product.

In many cases it will be impossible to collect all the data necessary for a good environmental evaluation. In such cases a qualified assessment will have to be made, on the basis of the existing information.

Given the wide range of environmental issues, it will probably be necessary to prioritise those issues of greatest concern. In line with the national environmental policy of the country, some issues may have a higher priority than others.

Aspects to be considered in the evaluation

Preliminary evaluation

- Is the Cleaner Production option available?
- Can a supplier be found to provide the necessary equipment or input material?
- Are consultants available to help develop an alternative?
- Has this Cleaner Production opportunity been applied elsewhere? If so, what have been the results and experience?
- Does the option fit in with the way the company is run?

Technical evaluation

- Will the option compromise the company's product?
- What are the consequences for internal logistics, processing time and production planning?
- Will adjustments need to be made in other parts of the company?
- Does the change require additional training of staff and employees?

Economic evaluation

- What are the expected costs and benefits?
- Can an estimate of required capital investment be made?
- Can an estimate of the financial savings be made, such as reductions in environmental costs, waste treatment costs, material costs or improvements to the quality of the product?

Environmental evaluation

- What is the expected environmental effect of the option?
- How significant is the estimated reduction in wastes or emissions?
- Will the option affect public or operator health (positive or negative)? If so, what is the magnitude of these effects in terms of toxicity and exposure?

5.4.5 Select options

The most promising options must be selected in close collaboration with management. A comparative ranking analysis may be used to prioritise opportunities for implementation. The concept of such a method is shown below in Table 5-3. An option can be assigned scores, say from 1 to 10, based on its performance against a set of evaluation criteria. By multiplying each score by a relative weight assigned to each criterion, a final score can be arrived at. The options with the highest scores will probably be best suited for implementation. However, the results of this analysis should not be blindly accepted. Instead, they should form a starting point for discussion.

All simple, cost-free and low-cost opportunities should of course be implemented as soon as possible.

Table 5-3 Example of a weighted sum method for evaluating alternative options

Evaluation criterion	**Weight**	**Score***					
		Option A		Option B		Option C	
		score	weighed score	score	weighed score	score	weighed score
Reduced hazardous waste treatment	3	+ 3	9	+ 2	6	+ 3	9
Reduced wastewater treatment costs	3	+ 1	3	0	0	+ 2	6
Reduced amount of solid waste	3	+ 3	9	+ 2	6	+ 3	9
Reduced exposure to chemicals	2	+ 3	6	0	0	–1	-2
Reduced amount of water consumption	1	+ 1	1	0	0	+ 2	2
Reduced odour problems	1	0	0	–1	–1	0	0
Reduced noise problems	1	–2	–2	0	0	0	0
Easy to install and maintain	3	–1	–3	-1	-3	+ 1	3
Weighted sum			23		8		27

* -3 = lowest rank, 0 = no change, + 3 = highest rank (preferred)

5.5 Implementation and continuation

The objective of the last phase of the assessment is to ensure that the selected options are implemented, and that the resulting reductions in resource consumption and waste generation are monitored continuously.

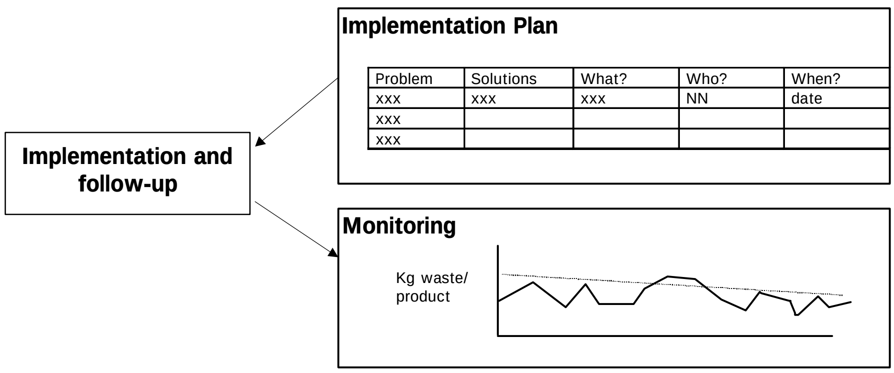

Figure 5—6 Implementation and continuation phase

5.5.1 Prepare an implementation plan

To ensure implementation of the selected options, an action plan should be developed, detailing:

- activities to be carried out;
- the way in which the activities are to carried out;
- resource requirements (finance and manpower);
- the persons responsible for undertaking those activities;
- a time frame for completion with intermediate milestones.

5.5.2 Implement selected options

As for other investment projects, the implementation of Cleaner Production options involves modifications to operating procedures and/or processes and may require new equipment. The company should, therefore, follow the same procedures as it uses for implementation of any other company projects.

However, special attention should be paid to the need for training staff. The project could be a failure if not backed up by adequately trained employees. Training needs should have been identified during the technical evaluation.

5.5.3 Monitor performance

It is very important to evaluate the effectiveness of the implemented Cleaner Production options. Typical indicators for improved performance are:

- reductions in wastes and emissions per unit of production;
- reductions in resource consumption (including energy) per unit of production;
- improved profitability.

There should be periodic monitoring to determine whether positive changes are occurring and whether the company is progressing toward its targets. Examples of the types of aspects that could be checked to evaluate improvements are shown in Table 5-4.

5.5.4 Sustain Cleaner Production activities

If Cleaner Production is to take root and progress in an organisation, it is imperative that the project team does not lose momentum after it has implemented a few Cleaner Production options. Sustained Cleaner Production is best achieved when it becomes part of the management culture through a formal company environmental management system or a total environmental quality management approach.

An environmental management system provides a decision-making structure and action plan to support continuous environmental improvements, such as the implementation of Cleaner Production.

If a company has already established an environmental management system, the Cleaner Production assessment can be an effective tool for focusing attention on specific environmental problems. If, on the other hand, the company establishes a Cleaner Production assessment first, this can provide the foundations of an environmental management system.

Regardless of which approach is undertaken, Cleaner Production assessment and environmental management systems are compatible. While Cleaner Production projects have a technical orientation, an environmental management system focuses on setting a management framework, but it needs a technical focus as well.

To assist industry in understanding and implementing environmental management systems, UNEP, together with the International Chamber of Commerce (ICC) and the International Federation of Engineers (FIDIC), has published an *Environmental Management System Training Resource Kit*. This kit is compatible with the ISO 14001 standard.

Like the Cleaner Production assessment, an environmental management system should be assessed and evaluated on an ongoing basis and improvements made as required. While the specific needs and circumstances of individual companies and countries will influence the nature of the system, every environmental management system should be consistent with and complementary to a company's business plan.

Table 5—4 Evaluation checklist

Overall Cleaner Production assessment check	**YES**	**NO**
• Are the opportunities implemented according to the action plan?		
• Are new procedures being followed correctly by the employees?		
• Where do problems occur and why?		
• Do licenses or permits require amendments? Which ones?		
• Has compliance with legislation been maintained as a result of the changes?		
Environmental performance check		
• Are the opportunities cost effective? Is the cost effectiveness as expected?		
• Has the number of waste and emission sources decreased? By how many?		
• Has the total amount of waste and emissions decreased? By how much?		
• Has the toxicity of the waste and emissions decreased? By how much?		
• Has the energy consumption decreased? By how much?		
• Have the Cleaner Production goals been achieved? Which have and which have not?		
• Have there been any technical ramifications? Which and why?		
Documentation check (The following items should be included in the files.)		
• Statements of the company's objectives and targets and the environmental policy		
• Company description and flow diagram with input and outputs		
• Worksheets completed during the Cleaner Production assessment		
• Material balances		
• List of Cleaner Production opportunities generated during brainstorming sessions		
• Lists of opportunities that are technically, economically and environmentally feasible		
• Implementation action plan		
• Monitoring data		
• 'Before-and-after' comparisons		
• Post-implementation evaluation reports		

Evaluation Questionnaire

CLEANER PRODUCTION ASSESSMENT IN DAIRY PROCESSING

As part of its continuing review of the quality and impact of publications it supports, the United Nations Environment Programme's Division of Technology, Industry and Economics would appreciate your co-operation in completing the following questionnaire.

1. Quality

Please rate the following quality aspects of the publication by ticking the appropriate box:

	Very good	*Adequate*	*Poor*
Presentation	❑	❑	❑
Structure of content	❑	❑	❑
Subject coverage	❑	❑	❑
Ease of reading	❑	❑	❑
Level of detail	❑	❑	❑
Rigour of analysis	❑	❑	❑
Up-to-date	❑	❑	❑

2. Usefulness

In general, how much of the publication is:

	Most	*About half*	*Little*
Of technical/substantive value to you?	❑	❑	❑
Relevant to you?	❑	❑	❑
New to you?	❑	❑	❑
Will be used by you?	❑	❑	❑

What would make the manual more useful for you?

____

3. Effectiveness in achieving the objective

The objective of this publication is to provide the reader with an appreciation of how Cleaner Production can be applied to the dairy processing industry as well as providing resources to help undertake a Cleaner Production assessment at a dairy processing facility. In your opinion, to what extend does this document fulfil this objective?

Please tick one box ❑ Fully ❑ Adequately ❑ Inadequately

Please state reasons for your rating:

____

____

4. Uses

a. Please state how the publication will affect or contribute to your work, illustrating your answer with examples.

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____

b. Please indicate, in order of importance (first, second or third), the usefulness of the publication to you:

	First	*Second*	*Third*
For your own information	❑	❑	❑
As reference material	❑	❑	❑
As guidelines for on-the-job application	❑	❑	❑

5. Distribution

Will others read your copy of this publication? ❑ Yes ❑ No ❑ Unknown

If 'yes', how many?

Did you receive this publication directly from UNEP? ❑ Yes ❑ No ❑ Unknown

If 'no', who forwarded it to you?

---

6. General Observations

a. Please indicate any changes in the publication that would increase its value to you.

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b. Please indicate, in order of importance (first, second or third), which of the following items might increase the value of the publication to you.

	First	*Second*	*Third*
Translation into your own language	❑	❑	❑
Specific regional information	❑	❑	❑
Additional technical information	❑	❑	❑

7. The following data would be useful for statistical analysis

Your name (optional)

Professional background

Position/function/occupation

Organisation

Country

Date

UNEP would like to thank you for completing this questionnaire. Please return to:

The Director

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Fax: +33 (1) 44 37 14 74

ANNEX 1 REFERENCES AND BIBLIOGRAPHY

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ANNEX 2 GLOSSARY

BAT	Best available technology and best available techniques (from an environmental viewpoint). BAT covers both equipment and operation practice
Best practice	The practice of seeking out, emulating and measuring performance against the best standard identifiable
BOD	Biochemical oxygen demand. A measure of the quantity of dissolved oxygen consumed by micro-organisms as the result of the breakdown of biodegradable constituents in wastewater
CFC	Chlorofluorocarbon. CFCs have very good technical properties as coolants, but are causing depletion of the ozone layer, which protect humans, animals and crops against ultra-violet radiation. CFCs and HCFCs (hydrogenated chlorofluorocarbon) are being phased out according to the Montreal Protocol. CFC-11 is commonly known as Freon
CIP	Cleaning in place is the circulation of a cleaning solution through or over the surface of production equipment
CO_2	Carbon dioxide
COD	Chemical oxygen demand. A measure of the quantity of dissolved oxygen consumed during chemical oxidation of wastewater
COD:BOD ratio	An indication of how biologically degradable an effluent is. Low values, i.e. <2, indicate relatively easily degradable substances, while high values indicate the contrary.
CP	Cleaner Production
Effluent	The liquid discharged from a process or treatment system
EMS	Environmental management system
Eutrophication	High growth of algae which causes a poor penetration of light in the water and a very high oxygen consumption, resulting in a high risk of fish death due to lack of oxygen
HCFC	Hydrogenated chlorofluorocarbon; see CFC
ISO 14001	International Standard ISO14001 Environmental Management Systems—specification with guidance for use. International Organization for Standardisation
MVR	Mechanical vapour recompression
PAHs	Polycyclic aromatic hydrocarbons. Occur in flue gases from combustion of fuel. Some PAHs are carcinogenic

pu	A measure of pollution units used in The Netherlands (1 p.u. equals the organic pollution of wastewater from one person)
PVC	Polyvinyl chloride, a commonly used plastic
N	Nitrogen
NO_x	Nitrogen oxides; covers both NO_2 (nitrogen dioxide) and NO (nitrogen monoxide)
P	Phosphorus
SO_x	Sulphur oxides; covers the various forms of gaseous sulphur oxide compounds found in combustion gases.
SS	Suspended solids
TVR	Thermal vapour recompression
UF	Ultrafiltration
UN	United Nations
UNEP DTIE	United Nations Environment Programme, Division of Technology, Industry and Economics
UNIDO	United Nations Industrial Development Organization
US$	US dollars

Units

bar	unit for measuring pressure (1 bar = 0.987 atmosphere)
J	joule (1 W = 1 J/s)
kg	kilogram
kW.h	kilowatt hour (1 kW.h = 3.6 MJ)
L	litre
lb	pound (1 lb = 0.454 kg)
m	metre
m^2	square metre
m^3	cubic metre (= 1000 L)
MJ	1 million joules (1 MJ = 0.278 kW.h)
MW.h	megawatt hour (1 MW.h = 1000 kW.h)
Nm^3	Normal cubic metre
t, tonne	tonne (= 1000 kg)

ANNEX 3 FURTHER INFORMATION

Journals

International Dairy Journal

Elsevier Science
P.O. Box 211
1000 AE Amsterdam
The Netherlands
(addresses for regional offices can be obtained from
http://www.elsevier.com/homepage/)
Phone: +31 20 4853757
Fax: +31 20 4853432
Email: nlinfo-f@elsevier.nl
Website: http://elsevier.com/inca/publications/store/4/0/5/8/6/0/

Bulletin of the International Dairy Federation (IDF)

41 Square Vergote
1030 Brussels
Belgium
Phone: +322 733 9888
Fax: +322 733 0413
Email: info@fil-idf.org
Website: http://www.fil-idf.org/Welcome.html

Journal of Dairy Science

American Dairy Science Association
1111 N. Dunlap Avenue
Savoy, IL 61874
United States of America
Phone: +1 217 356 3182
Fax: +1 217 398 4119
Email: adsa@assochq.org
Website: http://www.uniag.sk/~slpk/upi/dasci.html

Food Technology

Institute of Food Technologists
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Organisations

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This organisation publishes a number of useful resources, including the UNEP Technical Report Series, Cleaner Production and environmental management training packages and UNEP periodicals such as UNEP Industry and Environment Review. It also maintains the ICPIC database which contains Cleaner Production case studies (see database section).

UNEP Cleaner Production Working Group for the Food Industry

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Website: http://www.geosp.uq.edu.au/emc/CP/default.HTM

The aim of the group is to promote Cleaner Production in the food industry. The group's activities include maintaining a network of food industry and Cleaner Production experts, maintaining a library and database of information related to Cleaner Production in the food industry, delivering workshops and seminars and producing a newsletter.

United Nations Industrial Development Organization (UNIDO)

Vienna International Centre
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E-mail: zcsizer@unido.org
Website: http://www.unido.org/doc/f50135.htmls

UNIDO provides seminars, conferences, workshops, media coverage, demonstration projects, training and information dissemination. It also offers support in establishing National Cleaner Production Centres. Fifteen such centres had been set up by October 1998, with several more on the way.

Information manuals available from UNIDO include the UNEP/UNIDO Audit and Reduction Manual for Industrial Emissions and Wastes and UNIDO's DESIRE kit (Demonstration in Small Industries for Reducing Wastes). In addition, nine of the National Cleaner Production Centres have their own country-specific manuals. UNIDO has also prepared seven manuals specific to particular industry sub-sectors and has contributed to 26 UNEP Technical Reports on specific Cleaner Production options. All these publications can be obtained through UNIDO.

International Dairy Federation (IDF)

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Email: info@fil-idf.org
Website: http://www.fil-idf.org/Welcome.html

IDF is the dairy sector's international organisation that arranges each year a number of specialised events on all aspect related to the dairy industry. It also regularly publishes the *Bulletin of the IDF*, books and standard methods of analysis. Of special relevance is the IDF Standing Committee on the Environment, which deals with environmental issues concerning the dairy sector. The Committee's focus up to now has been on the control of water and waste water. IDF has member countries throughout the world. Contact can be made through the headquarters office in Brussels.

Food and Agriculture Organization of the UN (FAO)

Via delle Terme di Caracalla
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Website: http://www.fao.org/

FAO's aim is to raise levels of nutrition and standards of living, to improve agricultural productivity, and to better the condition of rural populations. It is active in the areas of land and water development, plant and animal production, forestry, fisheries, economic and social policy, investment, nutrition, food standards and commodities and trade.

It provides regular and comprehensive statistics on world food production and also commissions projects and publications related to the environmental sustainability of food production.

Cleaner Production on the web

UNEP International Cleaner Production Information Clearinghouse (ICPIC)

ICPIC is a Cleaner Production database containing case studies, publication abstracts, lists of expert organisations, and information on the resources available from UNEP DTIE. It is an electronic reference tool that is searchable by key word.

The database can be accessed via the internet at the site indicated below. A CD–ROM version of the database can also be ordered through the same website.

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Fax: +33 1 44 37 14 74
Email: unep.tie@unep.fr
Website: http://www.unepie.org/Cp2/info_sources/icpic_data.html

US EPA Enviroene

Enviroene is a database of information provided through the United States Environmental Protection Agency's website. It provides information on pollution prevention, compliance and enforcement. The information available includes pollution prevention case studies, pollution control technologies, environmental statutes and regulations, compliance and enforcement policies and environmental guidelines.

Website: http://es.epa.gov/

National Technology Transfer Centre, USA

At the National Technology Transfer Centre website you can search the internet for Cleaner Production cases.

Wheeling Jesuit University
316 Washington Avenue
Wheeling, WV 26003
United States of America
Phone: +1 80 06 78 68 82
Website: http://endeavor.nttc.edu/

EnviroNET Australia

The EnviroNET Australia website contains a wide range of Cleaner Production case studies from Australia.

Environment Australia
Environment Protection Group
40 Blackall Street
Barton ACT 2600
Australia
Phone: +61 2 62 74 17 81
Fax: +61 2 62 74 16 40
Email: environet@ea.gov.au
Website: http://www.erin.gov.au/net/environet.html

ANNEX 4 ABOUT UNEP DTIE

The mission of United Nations Environment Programme is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

The activities of UNEP DTIE, located in Paris, focus on raising awareness, improving the transfer of information, building capacity, fostering technology transfer, improving understanding of the environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and promoting global chemical safety. The division is composed of one centre and four units, as described below.

The **International Environmental Technology Centre** (Osaka) promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins in developing countries and countries with economies in transition.

The **Production and Consumption Unit** (Paris) fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

The **Chemicals Unit** (Geneva) promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety worldwide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).

The **Energy and OzonAction Unit** (Paris) supports the phase-out of ozone-depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of this unit.

The **Economics and Trade Unit** (Geneva) promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

For more information contact:

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